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SUMMARY REPORT

EVALUATION OF WATER YIELD POTENTIAL

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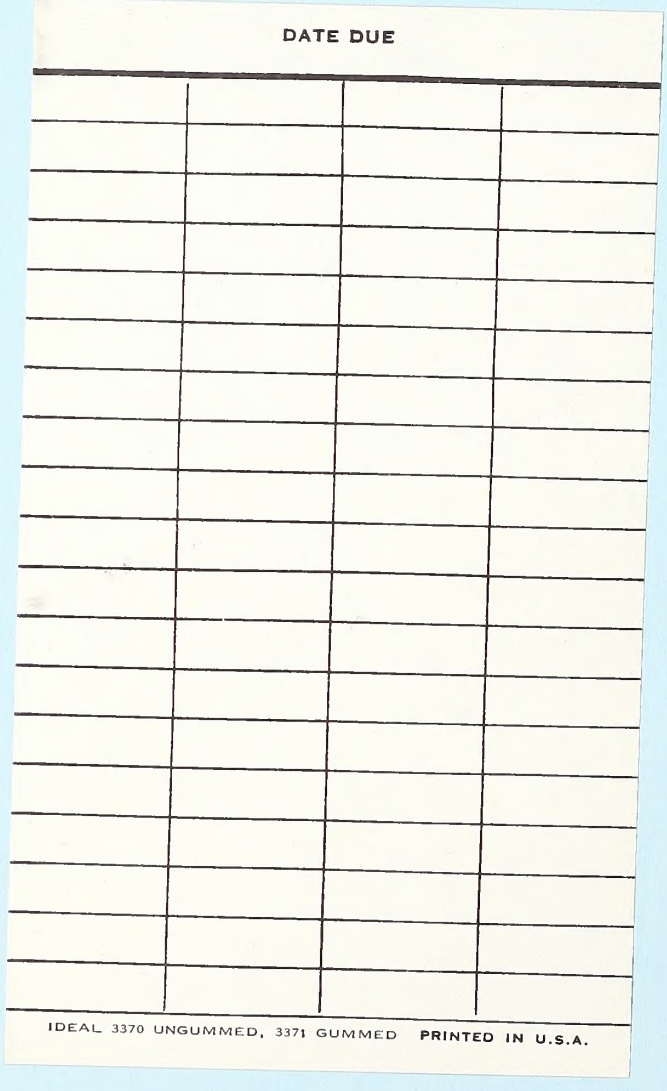

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SUMMARY REPORT

EVALUATION OF WATER YIELD POTENTIAL IN EAST PUTAH CREEK WATERSHED UNDER MULTIPLE USE MANAGEMENT

JULY 1975

(Issued May 1976)

Robert H. Burgy and others
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Summary of Five Annual Reports 1969-1975

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Contract No. USDI 53500-CTO-42(N)

TABLE OF CONTENTS

	Page
Summary and Conclusions	v
Introduction	viii
Description of the Watershed and Pilot Project	xii
SECTION I: WATERSHED PLANNING AND ANALYSIS PROCEDURES	I-1
SECTION II: HYDROLOGIC STUDIES	II-1
Water Yield Estimations	II-2
Review of the Response	
Summary and Results of Water Yield Estimates	
Conclusions	
Soil Erosion and Sedimentation	II-9
Review of the Response	
Summary of Sediment Analysis	
Conclusions	
Water Quality	II-13
Changing Water Quality with Watershed Management-- Review of Nutrient Response	
Summary and Results of Water Quality Monitoring Programs	
Conclusions and Recommendations	
SECTION III: AGRONOMIC STUDIES	
Introduction	III-1
Activities	III-1
Variety Testing	
Soil Fertilizer Tests	
Assays for Determining Mineral Status	
Survey of Cedar and Pocock Creek Watersheds	
Summary and Recommendations	III-14
Acknowledgments	III-17
References	III-18
Appendix A - Chemical Characteristics	III-19
B - Ranges in Concentration	
C - Effect of Increasing Calcium	
D - Exchangeable Calcium	
E - Exchangeable Magnesium	

Total Pages this Report - 160

Page

SECTION IV: THE MACROINVERTEBRATE FAUNA OF CEDAR CREEK

Introduction IV-1

Hydrobiological Studies IV-1
February 1971-August 1974
August 1974-June 1975
Study Site
Methods
Results and Discussion

Literature Cited IV-13

Appendix A - Hunting Creek Species List IV-14
B - Eticuera Creek Species List
C - Nevada Creek Species List
D - Putah Creek Species List
E - Total Organisms by Taxon

SECTION V: AN EVALUATION OF THE IMPACT OF CHAPARRAL CONVERSION

Introduction and Objectives V-1

Methods V-2

Results - Birds, Reptiles, and Amphibia V-6
Vegetation and Habitats
Cypress Woodland
Chaparral
Oak Woodland
Influence of Weather Conditions on Field Study
Amphibians and Reptiles
Birds

Discussion - Birds, Reptiles, and Amphibia V-31
The Aquatic Environment
The Terrestrial Environment
Changes in Habitat
Short-term Impact
Long-term Impact on Terrestrial Amphibians and Reptiles
Long-term Impact on Birds

Results - Mammals V-46
Deer Pellet Counts
Probable Effects of Chaparral Conversion on Mammal Species

Recommendations V-56

Literature Cited V-59

Appendix A - Tentative List of Reptiles and Amphibians V-61
B - Tentative List of Birds
C - Tentative List of Mammals
D - Chaparral Breeding Bird Census Plot Vegetation Analysis

LIST OF FIGURES

No.		Page
Plate I	Map - East Putah Creek Watershed	xv
I-1	Steps in the Planning Process for East Putah Creek Watershed	I-3
I-2	Geographic Determinants for Land Use	I-4
II-1	Annual Precipitation and Water Yield Increase Relationship	II-6
II-2	Electrical Conductivity vs. Discharge	II-20
II-3	Seasonal Nutrient Fluctuations	II-21
IV-1	General Map	IV-4
IV-2	Similarity Coefficients	IV-11
IV-3	Similarity Coefficients Each Collection Date	IV-11
V-1	Field Survey Sites on the Study Area	V-4

LIST OF TABLES

No.		Page
I	Chronology for the Acquisition of Data	x
III-1	Yield of Forage	III-6
III-2	Percent Clover	III-7
III-3	Percent of Square-foot Frames	III-9
III-4	Project Cost of Conversion	III-15
IV-1	January 1975-May 1975 etc.	IV-7
IV-2	Species Number, Standing Crop, and Diversity	IV-9
V-1	Amphibians and Reptiles Found in the Cedar and Pocock Creek Drainages	V-9
V-2	Resident Birds	V-14
V-3	Wintering Birds	V-19
V-4	Summer Residents	V-21
V-5	Migrants and Transients	V-24
V-6	Species Unrecorded	V-26
V-7	Results of Breeding Bird Census	V-29
V-8	Estimated Effects of Chaparral Conversion on Species of Mammals	V-47
V-9	Deer Pellet Plot Counts	V-49

SUMMARY AND CONCLUSIONS

This report has been prepared for the U. S. Department of Interior, Bureau of Reclamation and Bureau of Land Management to review the scope and principal results of research studies on the East Putah Creek Watershed conducted during 1969-75. Annual reports have been prepared during this period marking progress, and presenting new data, evaluations, and recommendations resulting from the investigation. These reports should be consulted for much of the detailed background on which the following summaries, conclusions, and recommendations are based:

- Water quality, suspended sediment, and hydrobiological studies have been explored so that ecological consequences of watershed development to tributaries of Upper Putah Creek can be evaluated.
- Baseline data has been gathered by continuous or periodic monitoring of the biological, chemical, and hydrological parameters for future assessment of watershed performance.
- Assessments of the present composition of aquatic biological species in Putah and Hunting Creeks have been reported. Biological sensitivity indices have been prepared which will aid in predicting impacts of management alternatives on aquatic systems. Emphasis has been upon the interaction between substrate type and benthic productivity.
- Agronomic studies in the greenhouse and the field have defined nutrient deficiencies and have indicated amendments needed for grass growth as well as species and revegetation techniques for serpentine soils in the project area.
- To substantiate projected water yield increases and subsequent watershed responses, a pilot project on a smaller watershed within the basin has been recommended by the USBLM and USBR.
- Wildlife inventory of Cedar and Pocock Creek drainages has been made and projected impacts from vegetative conversion evaluated.
- Planning criteria and guidelines have been incorporated into a management sequence that should be applicable to other areas and provide a basis for evaluating many factors for the various land use objectives. Constraints have been recommended for guidance in selecting sites suitable for conversion.
- Within this management program, the value of public input to the initial project formulation has been stressed. Coordination with public land

managers and private land owners would provide information on needs and desires for uses of the study area.

- A matrix has been developed for integrating a broad array of information into a compatible multiple use plan. Intercompatibility of uses, short term - long term effects, and on site - off site influences have also been determined.
- Identification of benefit and cost factors for management programs have been made. These factors are left to the agency for final assessment and dollar evaluation.
- The hydrologic responses of the gaged tributaries form the basis for testing the predicted change in magnitude of runoff as influenced by vegetative density and composition. The predicted yield increase estimate continues to appear significant.
- The first year of data indicates existing runoff as a percentage of precipitation to be about 47% for Pocock Creek and 42.5% for Cedar Creek.
- Modifications of natural systems alter nutrient concentrations in surface and subsurface flows. An understanding of the watershed system and its nutrient cycles is essential in determining the effects of chaining, fertilizer applications, and herbicide treatments. Seasonal fluctuations in nitrogen and phosphorus should be closely monitored to understand nutrient cycles and nutrient loading to streams. Calcium, phosphorus, and sulfate should be analyzed to determine the influence of fertilizer applications on stream water quality. Assessments of erosion on the watershed can be made by viewing changes in suspended sediment, electrical conductivity, magnesium, and sulfate.
- There is presently insufficient water quality data to adequately evaluate a conversion on Cedar Creek or Pocock Creek. At least one more year of water quality monitoring with complete testing is recommended, after which time, three years of baseline data will be available.
- Annual grassland species were successfully established on serpentine soils following clearing of brush with a brush rake on a bulldozer blade or by pulling a modified anchor chain twice over the brush.
- With certain modifications of the conversion procedure and follow-up management practices, wildlife benefits can be greatly enhanced for a number of species, both game and non-game. Suggestions of means for modifying treatments for brushland conversion are made.

- None of the vertebrates present in the Cedar and Pocock Creek drainages appears on the list of rare or endangered species.

INTRODUCTION

Development of additional, new water supplies and source-enhancement of existing supplies for California is a continuing challenge to all sectors of the State's economy. The practicality of all known methods of water yield enhancement is being given special attention by state and federal agencies, who are seeking to identify those alternatives with the greatest potential. The administrative agencies responsible for the operation and maintenance of water resource developments are aware of the needs for long-range management of watershed lands to promote water yields and to enhance, where possible, the environmental values of the areas.

Research on the hydrologic effects of vegetation management has clearly demonstrated the potential for additional water yield by reducing the loss of water by evapotranspirational use of non-economic brush and trees. Yet variable watershed characteristics influence the effectiveness of converting brushland to grassland, the quality of runoff waters, and the environmental consequences.

Early in 1969, in preliminary discussions between the U. S. Bureau of Reclamation and UCD representatives, the possible benefits of implementing research to assess these concepts on a specific water resource system were explored.

The U. S. Bureau of Reclamation together with the Bureau of Land Management is seeking to develop a multiple land use program for part of the Putah Creek Basin. This program will include, among other things, wildlife enhancement, fuel reduction for fires, with water yield improvement as a principal objective. Consideration of all related factors is desired. USBLM administers the public lands composing a portion of the Putah Creek watershed. Downstream the USBR operates the Solano Project, consisting of Monticello Dam on Putah Creek, forming Lake Berryessa, and the Putah South Canal which supplies water to lands within the Solano Project service area including the Solano Irrigation District, among others. Water service is also provided to various resorts on the west side of the lake.

Subsequently, on June 9, 1969, the Regional Director of the USBR for Region 2, now Mid-Pacific Region, requested the California State Director of the Bureau of Land Management to initiate a cooperative program of watershed improvement on BLM lands in the East Putah Creek watershed. The USBR's

principal interest is in evaluating the concept of increasing water yield by means of brush manipulation and land treatment. As a beginning, by virtue of BLM's basic agreement with the Regents of the University of California, a reconnaissance study was undertaken by the University under contract to the Bureau of Land Management, with funds provided primarily by the Bureau of Reclamation. Soil, vegetation, aquatic life, wildlife, and other resources and their uses on BLM lands were to be considered in arriving at the feasibility of producing additional water.

From these efforts has emerged the present contract research program which is summarized in this report. Significant hydrologic parameters involved in the management of the watershed, its soils and vegetation have been identified. Additionally, the present and future resource potentials of these lands, in terms of important uses and known values, are assessed in terms of geographic determinants.

Objectives

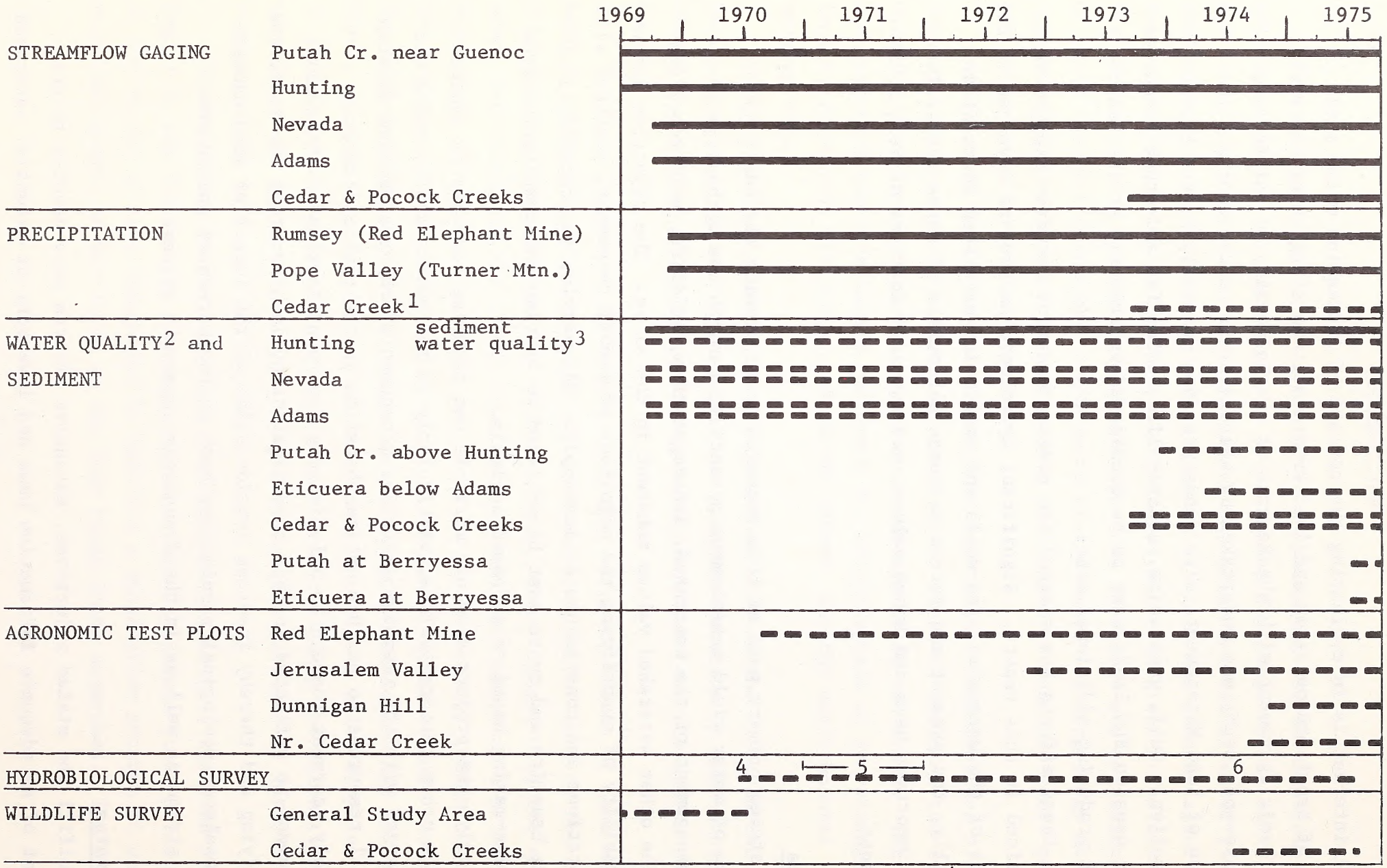
The stated primary goal of this research is to provide the basis for evaluation of water yield enhancement potential, through the mechanisms of planned management of the watershed, its vegetation, wildlife, soil resources and all the other watershed values inherent in the sites. The objective infers the desirability of quantifying the magnitude of runoff responses, together with such limitations and constraints as may apply. Ultimately, the capability of predicting benefits and costs must be achieved to provide the comparative data for decision-making based on economic analysis.

Secondly, the project examines multiple use planning concepts to enhance and protect other resource values, particularly in the public domain where the BLM is charged with the responsibility for management, conservation and development of all resources to produce optimum benefits in the public interest.

Finally, current concern by all citizens toward protection of the quality of environment is reflected in this investigation by incorporating the objective of identifying and thereby insuring consideration of the impact of land management proposals on ecological parameters, both on the watershed and on the tributary stream as well as in the downstream reservoir system.

Present Status

To fulfill the stated objectives, extensive efforts were devoted to the development of an adequate information base and inventory of essential watershed



[1]Additional storage gages located near Adams Peak, Hunting Cr., Devilhead Rd., Bishop Mtn., Adams Cr., Zim Zim Cr.

[2]Measurements include E. C., common nutrients, physical parameters, and heavy metals. Periodic sampling taken every six weeks.

[3]Mercury, Nickel, and Chromium are now being measured at all water quality stations as of Spring 1975.

[4]Putah & Hunting Crs.

[5]Putah, Hunting, Nevada, Eticuera Crs.

[6]Cedar & Pocock Crs.

continuous monitoring

periodic data collection

Chronology for the Acquisition of Data. Table I.

characteristics. Much of that information was presented in the form of resource inventory maps. New data on hydrologic characteristics of the region were acquired and deficiencies in basic data and knowledge of the region were identified. Succeeding phases of the study have directed efforts toward supplemental studies to meet the informational needs for a comprehensive watershed planning activity. The complex interrelationships among the several kinds of watershed lands, diverse ownerships and the many multiple purpose uses inherent in the region demand intensive study to permit development of effective, responsive programs for the area.

In order to assess the ecological relationships and environmental effects associated with land use and management studies, both the terrestrial and the aquatic components of the area have been surveyed. Field and laboratory research on special characteristics of the basin are included for problem soil sites and to quantify agronomic requirements. The various parameters surveyed on-site have been summarized in Table I. The chronology indicates location, length of record, and regularity of data collections which have been made.

The preliminary estimates of the water yield potential through vegetation control programs has been assessed annually by a comparative analysis of data from Adams, Nevada, Hunting, Cedar, and Pocock Creeks. Over a wide range of annual rainfall experience, including an extremely deficient year of about 16 inches compared with an annual average of 32-33 inches, the annual runoff comparisons continue to confirm the yield potential of 5.2 inches of additional runoff in an average rainfall year. It must be noted that all estimates and evaluations are based on data reported to the project in "preliminary form" and are therefore subject to revision and modification.

Procedures for watershed planning have been delineated, including criteria for selecting conversion sites, matrices for integrating multiple use information with natural determinants, and discussion of trade-off effects. To test the methodology and predicted response of the system, a pilot project has been recommended by the BLM and BR. If the project is successful, the results verified, and environmental alterations minimal, the analytical process could be applied to other regions.

DESCRIPTION OF THE WATERSHED AND PILOT PROJECT

The Upper Putah Creek Basin above Monticello Dam in Napa and Lake Counties is composed of 568 square miles within the series of intermountain valleys and ranges of the Coast Range Mountains of California. The total basin contains widely varied topography, the highest elevations being on the westerly side at Cobb Mountain, 4722 ft., and Mt. St. Helena, 4343 ft. and the lowest being on the southerly side at Lake Berryessa, 440 ft.

Precipitation varies from about 22 inches annually near Lake Berryessa to over 80 inches on the western slope. Rainfall is the predominant form of precipitation and averages about 33.5 inches on the Upper Basin.

The East Putah Creek Watershed Study Area in the eastern portion of the Upper Putah Creek Basin, consists of 65,000 acres--of which 25,000 acres are publicly administered. The Study Area is essentially at the Upper Basin mean with respect to elevation, and has precipitation of about 32-33 inches. The steep, high, westerly basin ridge acts effectively as a physical barrier and significantly influences storm movement and precipitation mechansisms so that the Study Area is essentially in a "rain shadow" (orographic effects). Rainfall (95 percent) comes in the seven-month winter period, October through April.

The Study Area differs somewhat from the more diverse Upper Putah Creek Basin. Major tributaries include Putah Creek (western boundary of the Study Area), Hunting Creek, Soda Creek, Zim Zim Creek, Nevada Creek, Adams Creek, Dyer Creek and many named tributaries of these, plus a number of smaller unnamed drainages. These portions of the Upper Putah Creek Basin surrounding the public domain are rugged, with steep terrain covered with diverse vegetation, a few small valleys of agricultural importance, limited access, with a few ranches, and mining operations.

Poor soil characteristics together with climate result in limited productivity. Low rainfall and shallow soils preclude occurrence of commercial forest species. The lands may be generally classed as marginal rangelands with local sites affording good forage.

Present land uses include ranch operation, some livestock grazing, mining operations (mercury, borax, cinder and pumice), extensive wildlife habitat for deer, quail and dove, and other game species, and a developing recreational use.

Lake Berryessa and the navigable portions of Putah Creek are providing ever increasing numbers of recreationists to the area via boats. New

subdivisions at the lake, as well as several developing upstream, are attracting people to the region, particularly on the west bank of Putah Creek. Recreational facilities associated with Putah Creek, Lake Berryessa, and ultimately to more remote sites in the Study Area, are the newest and perhaps the most significant utilization that can be foreseen. Recreational use of the public lands is being stimulated by the BLM and becomes increasingly attractive to potential user groups who desire the "wide-open spaces" at lowest possible cost. Creation of hiking trails, riding facilities and campgrounds, and especially access road improvements will undoubtedly result in greater usage and public pressure on the region. Hunting use is also likely to increase.

In terms of composition of the public lands, it is interesting to note the correlation between the marginal soil areas and chaparral vegetation and the public lands. These lands may be characterized as being of the poorer soil types, largely the ridge areas, and relatively inaccessible, due both to low needs and because they are partially cut off by the private ownerships surrounding them.

These observations lead directly to questions of management policy and suggest possible conflicts between various desired uses of the lands. Some of the requirements for present and proposed uses and other factors are discussed further in succeeding sections of this report.

The private lands in the Study Area have been only partially and incidentally surveyed as part of this investigation for future development plans. Owner contacts during field visits revealed some plans for improvement of grazing lands, proposed water storage works (dams and reservoirs), and some thoughts of subdivision. In general, however, except for water development and some ongoing vegetation control work by certain ranchers, no firm plans appear to exist. A survey of future plans in the area would be appropriate if and when a decision is made to develop a full scale conversion plan.

A survey has also been completed of existing, small water storage works and dams recently constructed. At the time of the survey in 1972, 37 reservoirs had been constructed, 34 of which retain usable water throughout the year. The total surface area is about 30 acres and maximum storage capacity of 195 acre-feet. Evaporative losses must be added to estimate the total effect.

The BLM and BR have proposed alternative sites for a pilot conversion project in the Cedar and Pocock Creek Drainages, southeastern tributaries to Hunting Creek above the confluence with Putah Creek. Cedar Creek has

a contributing area above the gaging station of about 2.1 square miles, with Pocock Creek having about 1.22 square miles. These watersheds have been studied for convertible acreage of brushland to grassland for water yield enhancement. Surveys included vegetation, soils, slopes, wildlife habitat, and stream gaging. Some water quality data has been gathered.

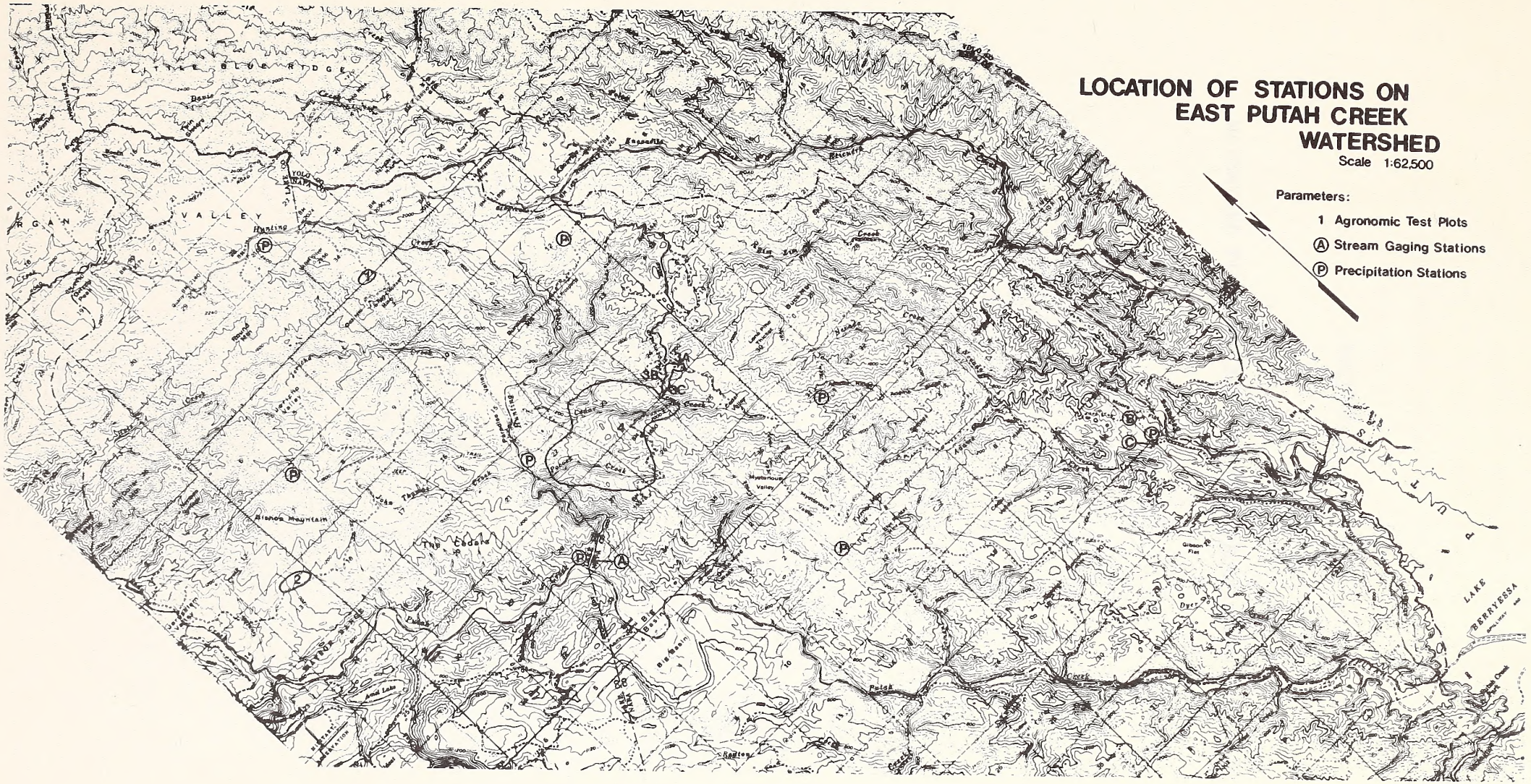

LOCATION OF STATIONS ON
EAST PUTAH CREEK
WATERSHED
Scale 1:62,500
Parameters:
1 Agronomic Test Plots
Ⓐ Stream Gaging Stations
Ⓟ Precipitation Stations
LAKE BERRYESSA

Plate I

SECTION I

WATERSHED PLANNING AND ANALYSIS PROCEDURES

SUMMARY

Lorene A. Jackson

PROCEDURES FOR WATERSHED PLANNING

The steps involved in the planning process have been delineated in graphical form in Figure I-1. The objective is to appraise the land use alternatives in the formation of a multipe-use management program. With five years of resource inventory, and interpretations, it should be possible to record a consistent and workable approach. Most of the baseline data has been gathered and monitoring programs are in effect. The project is on the verge of actual site determinations and to derive fullest value it is necessary to synthesize past steps and procedures into an organized methodology. This procedure could be tested on the proposed experimental sites within the Cedar Creek or Pocock Creek drainage basins or other sites that might be defined. If the project is successful and the results are verified, the analytical process can be applied to other regions.

The methodology has been discussed in greater detail in the 1974 Annual Report. The basic steps comprising the analytical approach are outlined as follows:

1. Identify potential land use alternatives for the specific project area.

2. Evaluate on matrices the degree of compatibility between each proposed land use.

3. Check each land use with existing conditions and natural determinants.

4. Determine requisite action for implementing each alternative. This includes selecting the appropriate method for each natural determinate. Project feasibility should be examined at this stage.

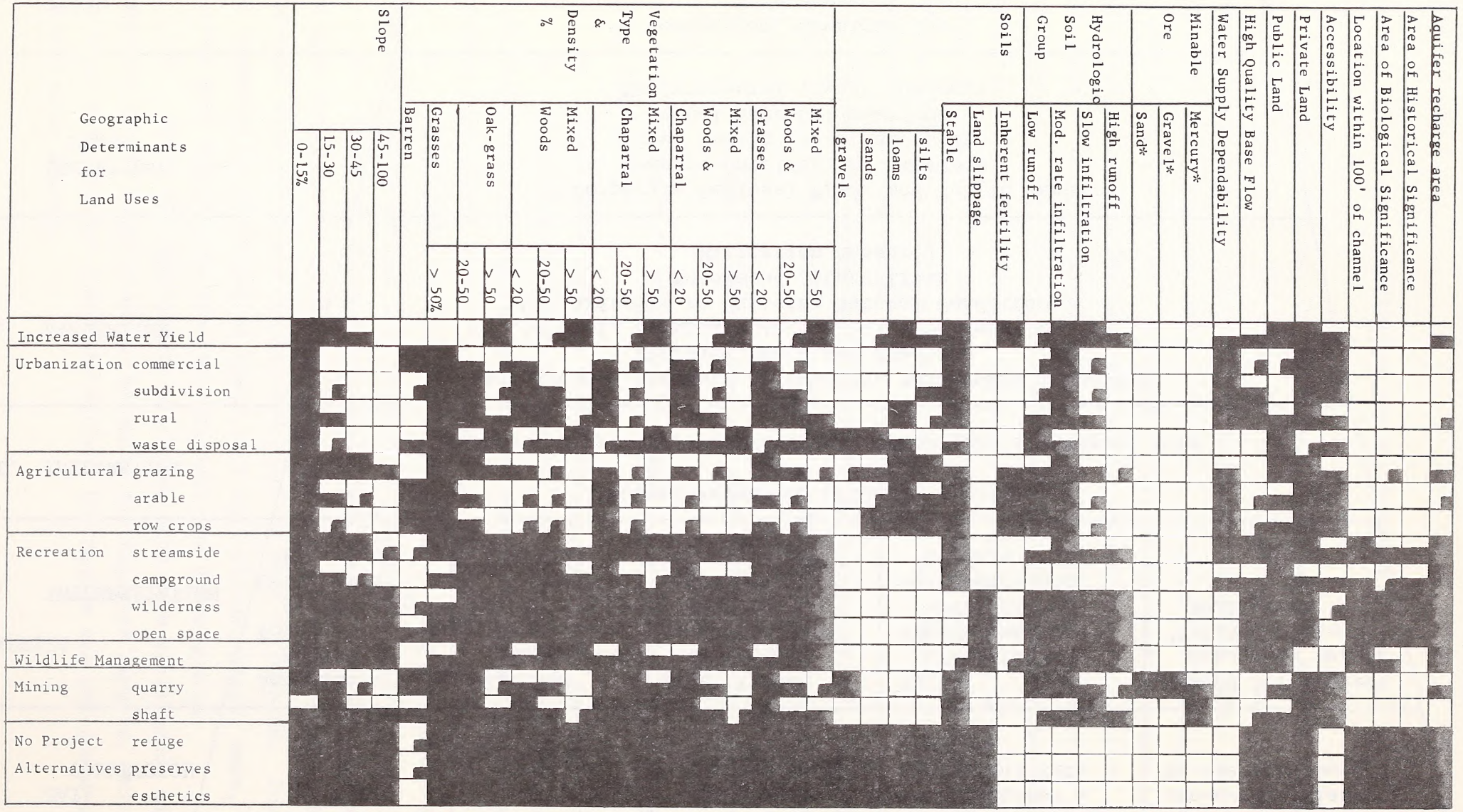
5. Identify the merits and limitations of each management alternative. This step should include a discussion of subsequent environmental effects.

6. Recommend the most desirable land uses. A value judgment must be made which should comply with Napa and Lake Counties' General Plans and the National Park Service's "Public Use Plan" as each is updated. Public input is essential at the decision phase such that places, areas, uses, and needs deemed most significant are employed into the value system.

7. After the appropriate land uses have been arbitrated, mitigation measures should be proposed to minimize the negative impacts. Mitigation measures must protect available options for future use and guard against irreversible actions.

STEPS IN THE PLANNING PROCESS	AGRONOMIC	HYDROBIOLOGIC	HYDROLOGIC	RESOURCE INVENTORY	SOCIO-ECONOMIC
INVENTORY I. DATA COLLECTION	Field & Lab Testing Soil-Vegetation Surveys	Aquatic Surveys	Hydrologic Data: Precipitation Runoff Water Quality Sediment Storage Survey	Soil Surveys Wildlife Inventory Vegetative Mapping Geologic Mapping Archeological & Historical Site Survey	Local Economic Conditions Land Ownership Agency Resources Landowners Plans Recreation Demand
ANALYSIS II. INTERPRETATION	Amendments Needed Forage Suitability Conversion Practices	Organism Sensitivity Assessment Stream Sensitivity Indices	Water Yield Potential Predicted Water Quality Changes	Soil Limitations Vegetative Convertibility Hydro-geologic Effects	Demand For Project Subsidies Needed "Public Interest" Evaluation
III. INTEGRATION	Assess Potential Effects (Matrix) Integrate Sensitivities, Problems, Restraints in Graphic Form				
IV. EVALUATION	Conceive and Evaluate Alternative Management Proposals Evaluate Costs and Benefits Identify Necessary Action for Effectuating Each Use Suitable to Existing Natural Conditions Recommend Alternatives Mitigation Measures				
V. CONCEPTUAL PLAN	Incorporate Regional Plans and Public Input Resolve Conflict in Interests Final Selection of Land Uses Actual Site Delineations Environmental Impact Analysis				
VI. TRIAL IMPLEMENTATION	Conversion, Construction Maintenance Monitor Results Verify Impacts and Methodology				

FIGURE I-1 STEPS IN THE PLANNING PROCESS FOR EAST PUTAH CREEK WATERSHED.



Degree of Compatibility

incompatible or unnecessary

low compatibility

medium compatibility

full compatibility

*blanks for Minable Ore indicate unrelated to use determination

FIGURE I-2. GEOGRAPHIC DETERMINANTS FOR LAND USE.

SECTION II

HYDROLOGIC STUDIES

Water Yield Estimates
Erosion and Sedimentation
Water Quality

Lorene A. Jackson
Robert H. Burgy

WATER YIELD ESTIMATIONS

The central theme of this study has been the derivation of an analytical approach and methodology for evaluating potential water yield increases on the East Putah Creek Watershed. Substantial supporting data has been developed to provide the background for an interpretation of the hydro-agronomic system which literally controls the redistribution processes acting on rainfall. Concern is presently directed toward the vegetation conversion of sites overlying serpentine soil.

A myriad of tests have been done relating vegetation conversions to changes in water yield. For years, conversion of brush covered slopes into grassland has been part of management programs for various purposes. For example, the USDA Forest Service and the California Department of Fish and Game are jointly exploring such management sequences for reducing wildfire fuel hazards while increasing wildlife habitats [refer to literatures for USFS Grindstone Canyon Project, University of California Hopland Field Station, Placer County Watersheds, and Piney Creek, Mariposa County]. However, responses to treatment are variable and often unpredictable. Hopefully, some of these variables for serpentine soils and mixed chaparral regions can be quantified in the East Putah Creek Watershed such that a conceptual model of the system can be derived and an evaluation scheme provided for multiple use planning.

Review of the Response

The hydrologic processes acting on a natural watershed involve the physical watershed parameters mentioned frequently herein; namely, watershed vegetation, soils, topography, subsurface geology, and to some extent, the type and intensity of surface activity. These elements react to the input of precipitation in predictable ways. Since the main form of input water on this study site is rainfall, only a liquid-phase water regime with short-term storage on the surface need be considered.

The role of vegetation in utilizing water potentially available to the watershed is the key to manipulating rates of runoff.

The initial interception loss of precipitation to the vegetative canopy can be reduced by substituting vegetative species of lesser height and foliage. Multi-storied shrubs and trees have greater loss through retention and subsequent evaporation than grasses [Reference 14]. The portion of rainfall retained in one or more levels of intercepting vegetation or surface litter

is essentially lost to the watershed. Changes in the density of vegetative cover can also influence the impact velocity of raindrops and the ensuing effects on the structure of the soil surface. Crusting of soil in a vegetated area is less than on an open or bare soil.

Perhaps of greater importance is the reduction of evapotranspirational losses by substituting vegetative species that have shallower root systems and shorter growing seasons. Perennial grasses will have no evapotranspirational demand during their dormant summer season. However, the rate of daily consumptive use (evapotranspiration) does not differ greatly between grasses and brush of the same cover density. Studies are presently being done on the influence of advection on evapotranspiration. It is believed that advection currents increase the evapotranspirational losses from brush above that of grasses. But, of more importance still, is the depth of rooting and season of growth.

Once established, high densities of grass can reduce the rate of overland flow by holding water, allowing it to infiltrate into the soil rather than wash away. This combined with reduced interception losses and reduced crusting of soil surfaces permits greater input of net rainfall into the watershed. In turn, the reduced evapotranspiration loss results in less watershed depletion. Succeeding rainy seasons thereby require smaller increments of recharge to satisfy deficits in both soil moisture and in groundwater storage. The net achievement is an increase in total water yield from the system [Burgy and Papazifiriou, 1971].

The redistribution of water resulting from the conversion of brushlands to grasslands has been demonstrated by storm hydrographs and comparative seasonal discharge before and after conversion. As noted, the increased yield may increase soil moisture recharge and total runoff. Hydrographs from isolated storms indicate reduced peak flow, but longer duration of flow. There may be a lag effect in heavily grassed areas. In the longer time period, groundwater recharge may occur, inducing stream flow during dry weather where no flow normally existed. The bulk of the increased yield occurs in prolonged late season flow and in greater contributions to the stream's base flow. Results from the University of California's Hopland Watershed indicated that one third of the increase appeared as direct runoff and two thirds appeared as base flow during wet and later dry seasons. Peak water yields may be in March, after which yields would be reduced by growth of grasses [Burgy, 1968]. Change in consumptive uses in the spring reflects both transpirational stress and period of active growth stimulated by increased solar radiation and transpiration.

An increased number of springs may appear throughout the watershed due to the greater base flow. Hewlett and Hibbert [1961] also suggest that yield is greater on north-facing than on south-facing slopes.

The amount of total runoff is a function of the moisture storage of the watershed. The amount of runoff is greater in a watershed that has low soil moisture storage. After several years of record, determinations can be made regarding the minimum quantity of precipitation required to satisfy the yearly deficit.

Variable watershed conditions determine the feasibility of conversion: Sites must have at least 50 percent cover of woody vegetation for the conversion to be hydrologically significant. To decrease erosion and slump problems associated with the additional increments of surface runoff, conversion should be avoided in areas of more than 45% slope (30% where there is low fertility). According to the U. S. Forest Service Brushland Management Environmental Statement, tractor clearing is normally limited to gentle or moderate slopes of up to 30%. Tractors can be used on steeper slopes where soils are stable and clearing is done along contours to minimize erosion. Sites should also be located 150 feet from the stream channel to act as a buffer zone for debris and to stabilize banks. Soil types should also be stable with medium drainage. For some wildlife habitats, it is preferred that conversions be done in narrow strips, more suitably, less than 200 feet (refer to Section V). Soil fertility must also be examined regarding amendments necessary to establish introduced species.

Summary and Results of Water Yield Estimates

Studies by the BLM have delineated the amount of convertible area within the Cedar and Pocock subunits of the Hunting Creek Basin. These figures are based on land ownership, 35% maximum slopes, suitability of vegetation, and on special reserved areas that are treatable but reserved for esthetic reasons, buffers, etc. These results have been summarized in the following table:

Stream	Drainage Area		Convertible Area	
	sq. mi.	acres	percent	acres
Cedar Creek	2.22	1,421	29	414
Pocock Creek	1.32	846	28	240

The hydrologic characteristics of these basins were compared using data obtained by the USGS starting in September 1969. Precipitation records were initiated in November 1969. Several approaches have been used to evaluate the available data and are briefly discussed herein:

1. Unit hydrographs were computed for the three gaging stations showing direct runoff for two isolated storm events occurring December 23-24, 1969, and January 8-10, 1970. Considering the relative runoff of the storm from each basin, Hunting Creek was most consistent, with a yield about 40 percent, which was nearly double that of the others.

2. A preliminary prediction graph was developed to augment data and quantify the yield where total yields are not yet known, Figure II-1. This graph is based on the relationship between annual precipitation and water yield increase consistent with known systems for the rainfall ranges depicted. For the average year with 32 inches of rainfall on the basins of the Study Area, this curve gives a predicted increase in runoff of over 5 inches annually. This will be distributed between direct runoff response and base flow.

3. Hunting and Nevada Creek data were used to derive response functions for the two watersheds for evaluation of differences attributable to vegetation variations. The vegetative survey data reveal Hunting Creek has been subjected to conversion to significant extent into grassland types (only 48% convertible area), while Nevada Creek remains largely in native cover (85% convertible). During the 1969-1975 study period, the average runoff from Hunting Creek was 60% greater than the average runoff from Nevada Creek. The reduced runoff in Nevada Creek is presumed to reflect the dense vegetative cover since vegetative types, soils, and topography are similar on these two drainage basins. This lends further support to the vegetation-density approach.

Correlation expressions have been derived between Hunting and Nevada Creeks' monthly runoff and the differential runoff. For more detail refer to the January 1972 Report.

4. The most direct method of quantifying yield is to calculate the percentage factor of current runoff. Four years of data have supported these predicted influences of vegetation.

It is interesting to note that during the low rainfall record in the 1971-72 water year, runoff for Hunting Creek was 0.93 inches while Nevada Creek produced 0.22 inches. Nevada Creek has a higher chaparral vegetative density than Hunting Creek that was clearly reflected by the reduced runoff. The nearly

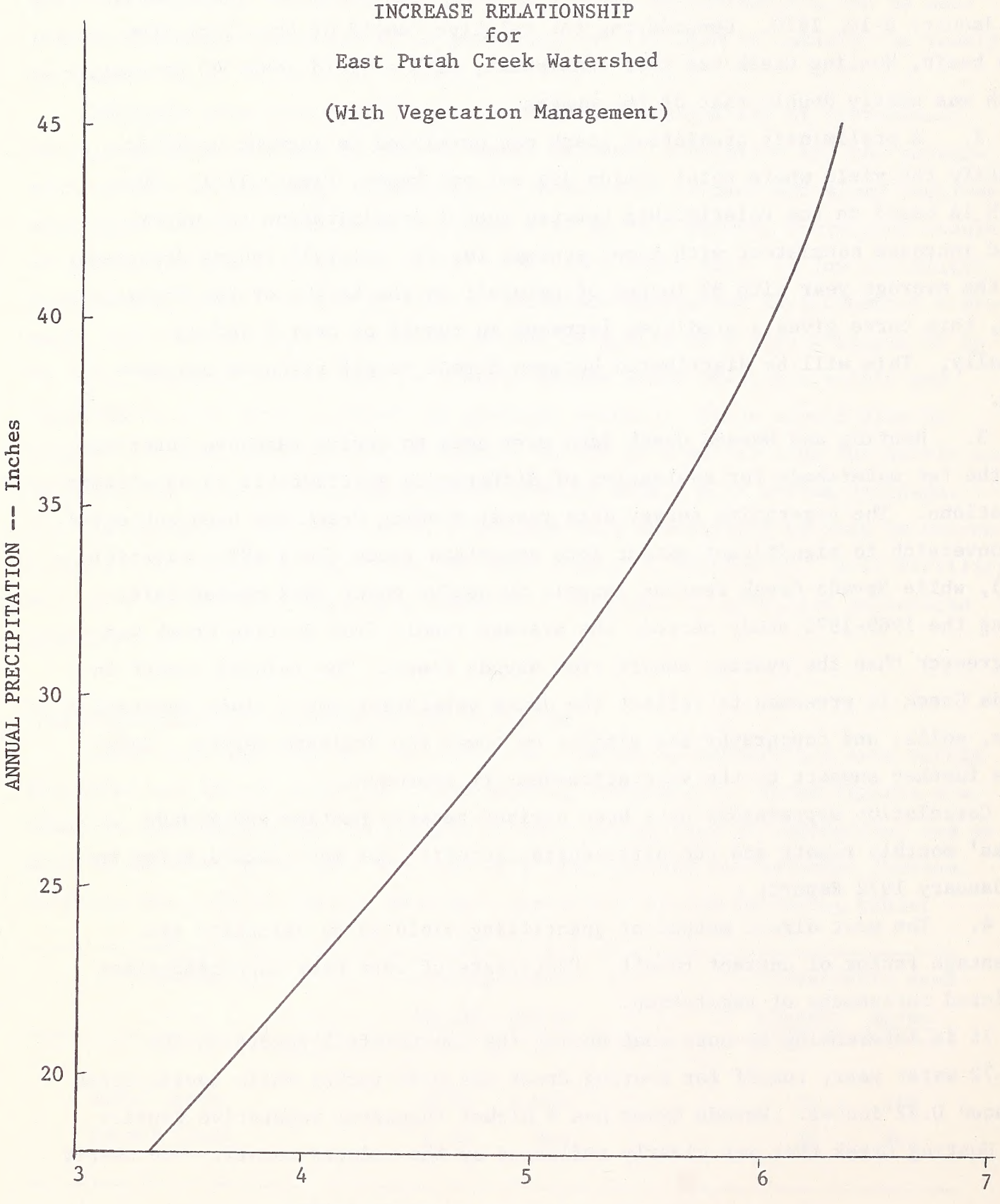
Figure II-1

PRELIMINARY ESTIMATE

ANNUAL PRECIPITATION AND WATER YIELD

INCREASE RELATIONSHIP
for
East Putah Creek Watershed

(With Vegetation Management)



fourfold difference of Hunting over Nevada Creek during an extreme low-rainfall period lends additional support to earlier suggested conclusions that the "vegetation management induced runoff changes" should be expected to be larger incrementally during dry years than during the wetter seasons.

The first year of data is also recorded for Cedar and Pocock Creek drainage basins. Percent runoff was calculated from an annual precipitation value of 35 inches, a real average from the Cedar Creek; near Devilhead Road, Knoxville; and Adams Peak precipitation storage gages. Unit runoff from Pocock Creek was 1.6 inches greater than Cedar Creek, a near 10% greater yield. This indicates similar storage capacities for both watersheds.

Annual unit runoff, rainfall, and runoff as a percent of rainfall volumes for the streams are presented in the following tables:

Water Year	Stream Runoff, Inches					Rainfall, Inches**	
	Hunting	Adams	Nevada	Cedar	Pocock	Rumsey	Pope Valley
1969-70	15.80	10.08	11.00				
1970-71	9.26	6.14	5.76			31.1*	28.2
1971-72	.93	.61	.22			15.5	16.1
1972-73	17.04	10.59	13.3			37.3*	36.5
1973-74	18.30	9.82	8.28	14.87	16.47	41.1*	37.2
						31.25	29.5

* value includes some estimated data

**additional hydrologic data may be available from the USBR

	Percent Runoff from Rainfall				
	1970-71	1971-72	1972-73	1973-74	
Hunting	29.8	6	45.7	44.5	Rumsey gage
Adams	21.7	3.8	29	26.4	Pope gage
Nevada	20.4	1.4	36.4	22.2	Pope gage
Cedar				42.5	1/
Pocock				47.0	1/

1/ Annual rainfall calculated from precipitation storage gages at Cedar Creek, Adams Peak, and near Devilhead Road southwest of Knoxville.

Conclusions

1. The first year of preliminary data indicate similar runoffs (values calculated as a percentage of precipitation) of 47% for Pocock Creek and 42.5% for Cedar Creek. Further data base is needed to substantiate these relationships.

2. Comparison of hydrologic data from Hunting Creek and Nevada Creek have been used to demonstrate changes in runoff due to vegetative manipulations. Nevada Creek remains largely in native chaparral cover, while Hunting Creek appears to have been subjected to significant prior conversions into grasslands. During the five year study period, the average runoff from Hunting Creek was 60% greater than the average runoff from Nevada Creek.

3. Predicted water yield increase estimates are considered to be reasonable for the specified conditions of vegetation density reductions envisioned as possible for the area.

4. After summarizing the results of the prior studies it is concluded the next rational step in the program must be a "testing project" to attempt to quantify the magnitudes of anticipated responses of the watersheds to the proposed management actions, including vegetation modifications.

SOIL EROSION AND SEDIMENTATION

A consequence of disturbances of any type on natural watersheds is erosion of soil and transport of the sediments from the watershed by runoff. Vegetative manipulation even under most carefully executed programs leaves soil surfaces temporarily exposed to wind, raindrop impact, and other abrasive forces. The subsequent loss of soil and vegetation can remove nutrients from the watershed, reduce storage capacity of downstream reservoirs, reduce benthos niches, and decrease hydrobiological activity, all of which could contribute to aesthetic loss, irreversible damages, and diminished recreational activities downstream and in lakes. The objective of this study is to determine, if possible, the relationship between additional increments of runoff and sediment transport.

Review of the Response

A brief discussion is presented here as a basis for analyzing preliminary sediment production on the measured tributaries. Erosion is used synonymously with denudation, classically referring to entrainment, transportation and deposition of debris. Two types can be identified, surface erosion and land slides.

In general, the following factors affect surface erosion:

1. Rainfall characteristics
   - Soil detachment (dispersion) is caused by raindrop impact.
   - Transport is controlled by the amount of overland flow and disturbance.
   - Dispersed particles seal the soil and reduce infiltration.
2. Soil erodibility
   - Soil properties affecting detachment and transport. The resistance of surface soil to detachment and transport is very closely related to water-stable aggregates.
   - Parent material generally exerts a great influence on the properties of upland soils - Wallis and Willen classify parent materials with respect to erosion as follows:
     a. Erodible parent materials - granite, quartz diorite, granodiorite, cenozoic non-marine sediments, schist
     b. Intermediate - diorite, a variety of metamorphic rocks
     c. Nonerodible - cenozoic marine, basalt and gabbro, pre-cenozoic marine sediments, peridotite, serpentinite, and andesite.

- Organic matter acts as a cementing agent in the formation of water-stable aggregates and as such is closely related to soil erodibility.
- Ions absorbed on the exchange complex in the soil have strong influence on erodibility by causing either flocculation or dispersion.
- Infiltration. The rapidity with which water flows into and through the soil profile has a great impact on soil erodibility. Stable soils will erode rapidly if rainfall intensities exceed the infiltration capacity for long periods of time. In vegetative areas infiltration is influenced by the amount of dead material and the percentage of non-capillary pores in the surface soil.

3. Topography
   - Percent slope and slope length.
4. Plant cover
   - The greatest deterrent to soil erosion is cover.

In the erosion process, rain acts in two different ways: the raindrop impact produces dispersion of the soil, and rainwater in the form of overland flow removes the dispersed material. The resistance to erosion of soils depends on the shear stress of flowing water. Tests have shown that resistance to erosion increases as the percentage of aggregating materials increase. Vegetation provides additional cohesion as well as protection from mechanical disturbance, and from direct impact by raindrops [Chow, 1964].

Removal of vegetative cover and substitution by grasses will have the following results relative to landslides.

- Removal of the mechanical reinforcement provided by the root system of the trees.
- Increased runoff, temporary increase in amount of suspended sediment, increased bank scouring and cutting, greater bedload, followed by net reduction in suspended sediment.
- Decay of plant roots results in piping, subterranean erosion.
- Higher soil moisture, saturated zone rises and may reach soil surface.
- Increased seepage.

All the above changes favor higher shear stress and reduce shear strength. The removal of the mechanical reinforcement provided by the root system of the vegetation alone, assuming no other changes occurred, may influence the occurrence of landslides. The incidence of landslips in the serpentinitic soil system has been noted to be relatively low.

The presence of suspended particles in the water and the movement of larger particles of sediment along the bed of streams adversely affects the use of water for most purposes. The transportation of sediments in streams depends upon size and density of the particles and is usually described as:

Bed load - Large particles intermittently rolling along the stream bed.

Suspended load - Particles entirely supported by water (fine sand, silt, clay).

Bed material load - The bed load plus suspended particles periodically resting on the bed during transport.

Wash load - Suspended particles which practically never rest on bed (clays and fine silts).

The suspended sediment and the wash load fraction is very important in water quality considerations. The wash load in particular depends on the rate of erosion of the area drained. Because of the very complicated factors involved, predictions of suspended and wash load concentration are difficult. Studies at present can only be made empirically.

Summary of Sediment Analysis

Several approaches are being used to accumulate baseline data to study effects of specific land uses on sediment production.

1. Measurements of suspended load in the study area were started in 1970. Only a very limited amount of data at scattered times are available for Adams and Nevada Creeks. A more complete set of data is available for Hunting Creek for the period December 1970 - December 1975. Presently, suspended sediment concentrations are being sampled automatically by the USBR at the Hunting Creek gaging station, periodically on Adams and Nevada Creeks, and most recently on Cedar and Pocock Creeks. Samples are analyzed by USGS.

No analysis of suspended sediment data has been made since no verified hydrologic data are available for Cedar and Pocock Creeks. Additionally, detailed hydrographic information is required rather than mean daily flows. Past reports presented a comparison between suspended sediment concentration and stream-flow for specific storm durations on Hunting Creek in December 1970 and January 1971.

The drainage area under study has almost no precipitation from June through September, and returns to a dry condition each year. All variables noted previously would experience their full range, and would return to that

prevailing after a dry period. A plot of data based on streamflow and sediment production summed over each hydrologic year could be expected to provide a useful relationship for prediction.

2. A survey of small storage structures was carried out in 1971 to examine rates of sedimentation and indications of accelerated erosion from changing land uses. Follow up surveys of condition at the inlets and in the bottoms of some reservoirs are necessary to determine actual amounts and rates of sediment deposition. Since there are no significant sized reservoirs in the pilot project area, no follow-on work is planned.

3. Aerial photographs have been used in an initial survey to identify slippage and apparent disturbed areas on Cedar and Pocock Creeks. The locations of these occurrences are important when designating sites for vegetative conversions. Constraints shouls be applied to these critical and unstable sites. The use of sequential aerial photography to denote new landslides, may aid in accounting for anomalies in suspended sediment data.

4. Hydrobiological studies are also being carried out to establish indices relating sedimentation to macrobenthic communities. Influences upon aquatic biota are an integral part of predicting the impact of increased sediment loads in streams (refer to Section III).

Conclusions

No conclusions can be drawn from data for Cedar and Pocock Creeks available at the time of this assessment due to the shortness of the record and preliminary (unverified) values.

WATER QUALITY

Increasing the yield of a watershed is of little value if the quality of additional increments of water are poor or if existing and future supplies are impaired. The chemical composition of natural waters is affected by the soluble products from the weathering and decomposition of rocks and soils. The quantity of dissolved minerals depends primarily on the type of rocks and soils with which natural waters come in contact. In general, ground waters have a higher mineral content than surface waters due to longer contact time. The processes involved are ion exchange between soil solutions and the soil itself, precipitation and dissolution of slightly soluble salts, and leakage from intrasystem cycling such as vegetation.

Considering a watershed system which is unaffected by man, water is delivered to this system as precipitation, which brings with it some quality constituents conveyed from the ocean or picked up in the atmosphere. Some precipitation may pass directly by overland flow to water courses, and the balance may infiltrate into the soil to reappear at a lower point in the system at a later time. Overland flow, interflow, and base flow each contribute quality constituents to the flow, the components varying throughout the hydrologic year.

The influence of man-induced activities on water quality cannot be deemed insignificant. As Sylvester [1960] reported, modifying natural conditions generally increases the concentration of nutrients in surface and subsurface flows. Regular examination of the water quality can indicate what processes are being carried out in the watershed, especially with changing land use. Significant water quality parameters which must be examined as an integral part of assessing watershed responses from brush conversion or more intensive multiple use of the watershed are:

- suspended sediments and turbidity
- nutrients
- temperature
- dissolved oxygen
- metals, and
- herbicides.

While water turbidity and temperature are important water quality problems, increasing concern is being expressed over nutrient losses following timber harvesting operations and similarly brush conversions in chaparral regions. Accelerated loss of nutrients following the cutting of natural vegetation

might result in accelerated eutrophication of streams and impoundments. Thus, nutrient cycling may become important when viewing the potential conversion of areas within the East Putah Creek Basin and the eventual input to Lake Berryessa. If considerable amounts of nutrients are lost in terms of total nutrient budget on the watershed, site productivity may be reduced.

With a conversion of brushlands to grassland, water pathways are essentially the same; however, the amount and rate of flow through each component may be altered. This is where the dynamics of the process needs to be monitored in regards to water quality. Vegetative conversion influences the nutrient flow through the system, 1) by the increased flow of water itself, and 2) by modification of nutrient cycles due to changes in the type and density of vegetation.

Changing Water Quality with Watershed Management - Review of Nutrient Response

1. Increased Water Yield to the System - Until dense grasslands are established, surface runoff will be increased, causing erosion, sedimentation, and removal of immobile nutrients such as phosphorus from the watershed to the stream. Nutrients will be added to the stream as particulate matter as well as in the dissolved phase [References 13, 14]. In the adjustment period, infiltration rates are reduced, providing less opportunity for water to come into contact with soluble chemical constituents of the geologic units.

Once dense grass cover is established, infiltration is increased due to the retention ability of grasses. The effective increase in water yield by conversion allows a greater volume of water for diluting nutrient concentration. Increased percolation also allows greater leaching of elements through the soil profile. Shallow grass roots reduce the depth of evapotranspiration, allowing more water to be stored in the soil, and expanding soil-water contact time.

Changes in the flow regime also influences ion exchange between the soil particles and the soil water. Surface-active constituents of soils that have cation-exchange properties are collectively termed the "exchange complex" and consist for the most part of clay minerals and organic matter. Equilibrium exists between the soluble and exchangeable cations in the soils. Therefore, with variations in moisture content, the changes in relative and total concentration of soluble cations are accompanied by changes in the relative composition of the exchangeable cations. Higher valence cations such as

calcium (Ca) and magnesium (Mg) tend to replace lower valence cations such as sodium (Na) and potassium (K) in the exchange complex, leaching Na and K through the soil. Increased runoff waters may contain a greater proportional increase in Na than of Ca and Mg. A view of the soluble sodium percentage (SSP) can also be used to examine mechanisms of the watershed. Total soluble cations increase in the direction of moisture migration. However, since the study site is predominately serpentine, the amount of Na and the SSP being low, increases in the sodium concentration of runoff waters would not be sufficient to alter the water quality significantly.

2. Chaining to Remove Vegetation - The conversion process itself will also affect the soil structure in these watersheds. The mechanical action of tractors and anchor chain will loosen the soil, allowing the planting of seeds, as well as increasing the susceptibility to erosion. Crushed brush left in place will aid in retarding soil erosion. The grass stands themselves will till the soil more uniformly than the brush cover, although the effective root zone is much shallower.

3. Modification of Nutrient Cycle - In the mature watershed, an increasing proportion of nutrient capital is tied up in nondeciduous biomass. The nutrients in nondeciduous parts fall to the soil surface; decomposition releases nutrients with portions returning to the soil, and some taken up again by vegetation.

When the vegetation is chained and debris left on the watershed, the intrasystem cycling is altered. Nutrients released in decomposition will either be recirculated into the soil and taken up by new grass stands or carried away by runoff water. As demonstrated at Hubbard Brook, N. H. [Licken et al., 1970], "complete devegetation results in higher nutrient availability due to acceleration of the nitrification process and more rapid decomposition of organic matter." If there is no living vegetation to absorb nutrients, leaching to streams is increased. This emphasizes the need for rapid establishment of grass stands and the maintenance of vegetative buffer zones. Shallow tillage of these nutrients into the soil will reduce some of this loss. In general, research indicates an increased wave of nutrients in the adjustment period following conversion. With proper management such as selective devegetation and rapid establishment of grass stands, the amount of nutrients discharged following cutting are generally small in terms of the total nutrient capital and should not reduce site productivity.

During initial cutting, lack of cooling from transpiring vegetation and cover from incoming solar rays will cause temperatures on the study site to increase. This in turn will increase microbial activity in the breakdown of litter. The added activity of microbes raises the bicarbonate anion level (due to released CO_2 combined with water) which leaches cations from the system.

Once a dense grass cover is established, nutrients will be cycled through the system again. However, the organic matter cycled through the system will be reduced from the previous brush cover. There will also be less nutrient removal occurring at lower depths due to shallower roots.

Seasonal fluctuations in nutrient loading to streams should be monitored and included in the analysis. This should establish correlations with plant growing requirements. During the growing season, plant uptake theoretically reduces the amount of nutrients released to the stream. Nitrogen has been used to indicate this. In an undisturbed system, ammonium and available nitrates are readily utilized by the growing vegetation, and nitrate concentrations in stream water are at a minimum. In the fall, as vegetation becomes dormant, concentrations in streams rise and reach a peak in early spring. On the other hand, in a clearcut watershed, nitrate concentrations in the stream steadily increase through the summer period until the fall when microbial nitrification diminishes or the supply of available ammonium ions becomes relatively depleted [Pierce et al., 1970].

It is important to emphasize the dynamics of these nutrient pathways. Nutrients are not present in only one phase - mineralization, fixation, and immobilization may all be occurring simultaneously on a site. Systems are continually striving for equilibrium. According to this, high levels of nitrate ions in the soil solution indicate a corresponding cation concentration and ready leaching.

4. Application of Fertilizers - Since soil in the study site is low fertility serpentine, the establishment of grass stands is dependent upon fertilization. The BLM/BR have prescribed treatment requiring aerial applications of superphosphate and gypsum. Water quality of the stream may be directly affected by drift. This can be avoided by proper constraints on applications: Applications should be made away from natural channels when wind speed is less than 6 mph, temperature below 75°F, and relative humidity above 30% [USFS, 1972]. Careful analysis of phosphorus, calcium, and sodium concentrations in streams should be carried out before and after fertilizer

applications. Precipitation and runoff shortly after conversion may wash additional amounts of phosphorus into waterways. Calcium exchange in the soil may release sodium, ammonium, and potassium into the water.

5. Application of Herbicides - To maintain grass over the long term, the brush regrowth will be controlled by aerial applications of 2,4-D and 2,4-5TP (Silvex). Both of these herbicides are relatively insoluble, absorbed by the soil, and degrade readily. The principle threat to water quality is runoff soon after application. Herbicidal treatments will also temporarily increase organic matter.

Fredriksen et al. [1974] carried out a study on herbicide treatment in Douglas-fir regions. Results over eight years of monitoring have been rather consistent, despite variations in chemicals used, season of application, and nature of the study sites. Shortly after application, some herbicide was found in most streams draining the treated areas. Residue did not persist for more than a few days. Drift or direct application to surface waters was the cause of most contamination. The authors reported there had not been a single instance in any Northwest forest stream where herbicide residues were detected more than one month after application. Nevertheless, it is recommended that sensitive indicators be placed at the streams to detect spills during aerial application.

These responses have been substantiated mainly by state of the art research. However, most of these studies have been on forested watershed for logging and silviculture practices. There seems to be a general lack of data collected on nutrient pathways affected by conversion of brushlands, despite the abundance of such brushland programs.

Summary and Results of Water Quality Monitoring Programs

The main objective in this evaluation program has been retrieval and inventory of baseline data to allow comparisons with post conversion conditions. Emphasis within the inventory has altered with time.

1. Initial efforts entailed a reconnaissance field sampling of ground and surface waters of the East Putah Creek Drainage Basin to identify and confirm water characteristics and related geology.

The survey indicated that the chemical quality of ground and surface waters ranges from excellent to very poor. The quality and chemical type of the water is most consistent for wells and springs in the ultrabasic rocks and in streams that drain this rock type. Although this water is relatively

low (406-675 mg/1) in dissolved solids, there is sufficient boron concentrations, particularly in the surface water to create a hazard were it used on boron-sensitive crops. The one occurrence of boron above 0.5 mg/1 in 10 analyses for ground water from the ultrabasic rocks is found in water from a spring draining an old mine shaft located near Knoxville.

The quality and chemical type of water from the Cretaceous sediments, Franciscan formation and Pleistocene volcanics vary widely, except for surface water from the Ultrabasic and Franciscan formations which are magnesium bicarbonate waters. Boron is high in some analyses of water from each of the above rock types. The highest boron concentration was 5.9 mg/1. (Refer to 1st Annual Report, July 1970, for further discussion and data on chemical classifications, concentrations, and locations of samplings.)

2. Once preliminary data was received from gaging stations on stream flow and water quality, relationships and interpretations could be made. Some general observations regarding chemical composition of runoff water were made in January and August 1972. Comparisons were also presented of the chemical quality of streamflows produced by tributaries of differing vegetative composition and density, geology, and soil types. Nevada Creek Basin is largely Franciscan formation geology and soil types, while Adams and Hunting Creeks lie in the serpentine soil areas.

For the 1970 spring-summer recession period, concentrations of magnesium, sodium, bicarbonate, chlorine, and electrical conductivity increased with declining stream flow. Calcium increased with lower flows in Adams and Nevada Creeks, but decreased with low flows in Hunting Creek. This suggests that the low calcium inherent in the serpentine soils of Hunting Creek is limiting. Periodic water quality samplings since these preliminary observations have generally agreed with these results for the spring-summer recession. Extreme storm events and low flows mask comparisons for the rest of the year.

3. As previously stated, attention is now being directed toward nutrient cycles, seasonal fluctuations, and relationships to vegetation that will be influenced by a conversion. Seasonal cycles should be determined in order to evaluate nutrient changes that may be masked by dilution effect of increased runoff.

Nutrient data has been very sparse before 1974, continuous data had been maintained primarily for discharge, suspended sediment, and electrical conductivity. In 1974, more data became available on nitrogen and phosphorus concentrations. Data is still inadequate to make an assessment on nutrient cycling.

at this time. The rather sparse data for Hunting, Adams, and Nevada Creeks, where conversion is not likely for several years, has caused attention to be directed to the BLM/BR proposed pilot project area. Monitoring was initiated in Cedar and Pocock Creeks in August 1973 and retrieval of preliminary data is still minimal. However, it is necessary to present some basic format and considerations for an adequate evaluation.

A comparison of electrical conductivity (E. C.) is presented in Figure 1 for Cedar, Pocock, and Hunting Creeks. E. C. relative to the normalized discharge per square mile is greater for both the tributaries than to Hunting Creek.

A brief qualitative classification of irrigation waters is included here to aid in the interpretation of data on E. C. (measure of salinity), boron, and sodium percentage. Because of all the variables involved, classification of waters for specific uses must be somewhat arbitrary and limits cannot be too rigid. Many studies have been done on irrigation uses and have resulted in the division of waters into the following broad categories [SWRCB, 1973].

	Class 1 Excellent to Good	Class 2 Good to Injurious	Class 3 Injurious to Unsatisfactory
E. C. x 10^6 at 25°C	less than 1000	1000-3000	more than 2500-3000
Boron, mg/l	less than 0.5	0.5-2.0	more than 2
Sodium percentage	less than 30-60%	30-75%	more than 70-75%

A preliminary view of the nutrient cycles is presented in Figure 2. Concentrations of total nitrite-nitrate in Hunting Creek decline steadily from January to April and are low throughout the summer. This correlates with heavy nutrient demands by vegetation and increased heterotrophic activities associated with the warming soils. Pocock Creek appears to have a much more balanced cycling of nitrogen within the watershed than Cedar Creek which seems to be subject to greater leaching. NO_2-NO_3 concentrations were used for the analysis since nitrate is the nitrogen form which may stimulate phytoplankton growth, whereas organic nitrogen, amino acids, and ammonia may inhibit biological growth. Nitrites are quickly oxidized to nitrates and do not comprise a significant portion of the NO_2-NO_3 values. Nitrates are the end product

Figure II-2

Electrical Conductivity vs. Discharge

at Hunting Creek

Cedar Creek

Pocock Creek

1974 Water Year

Preliminary

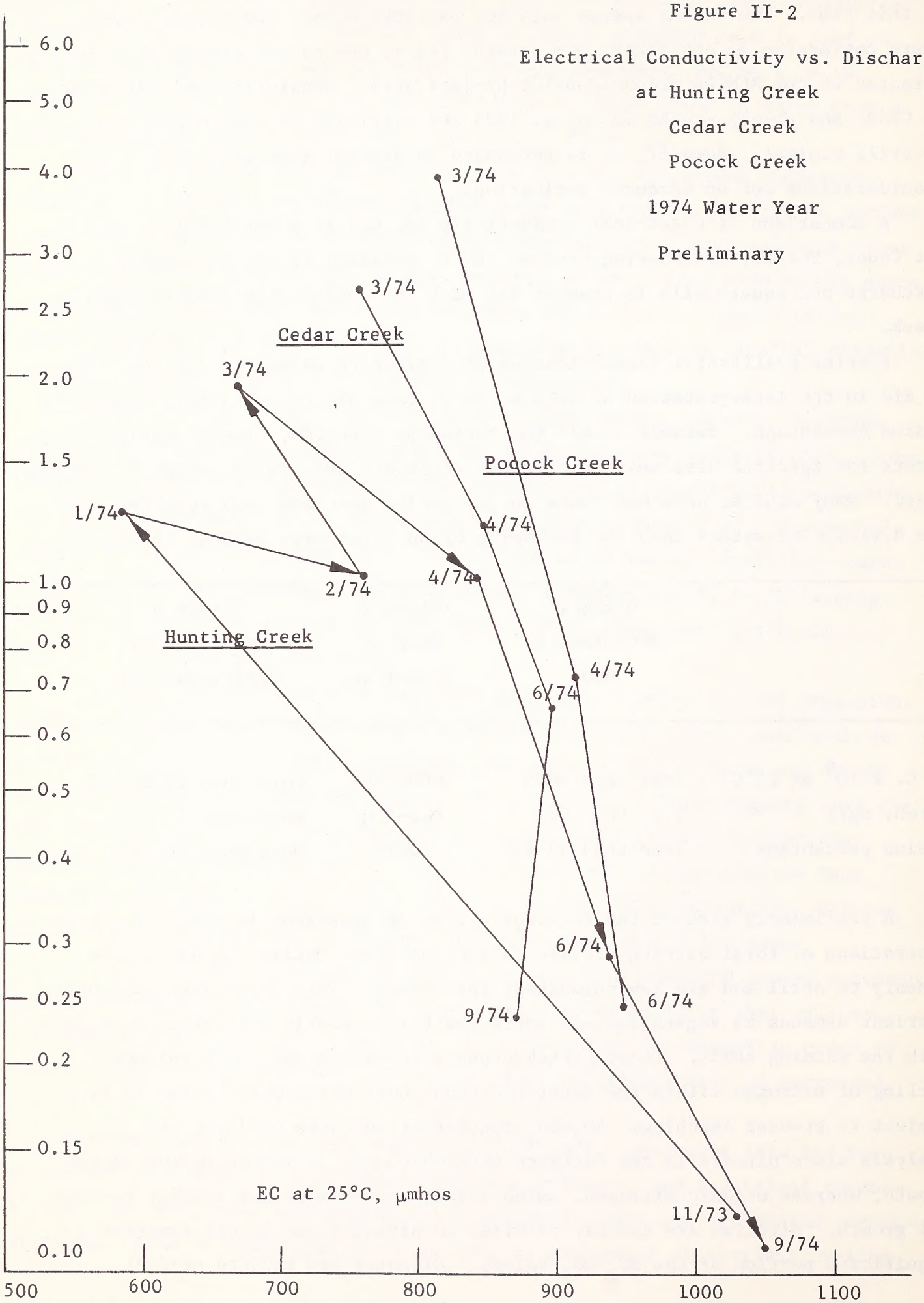


Fig. II-3

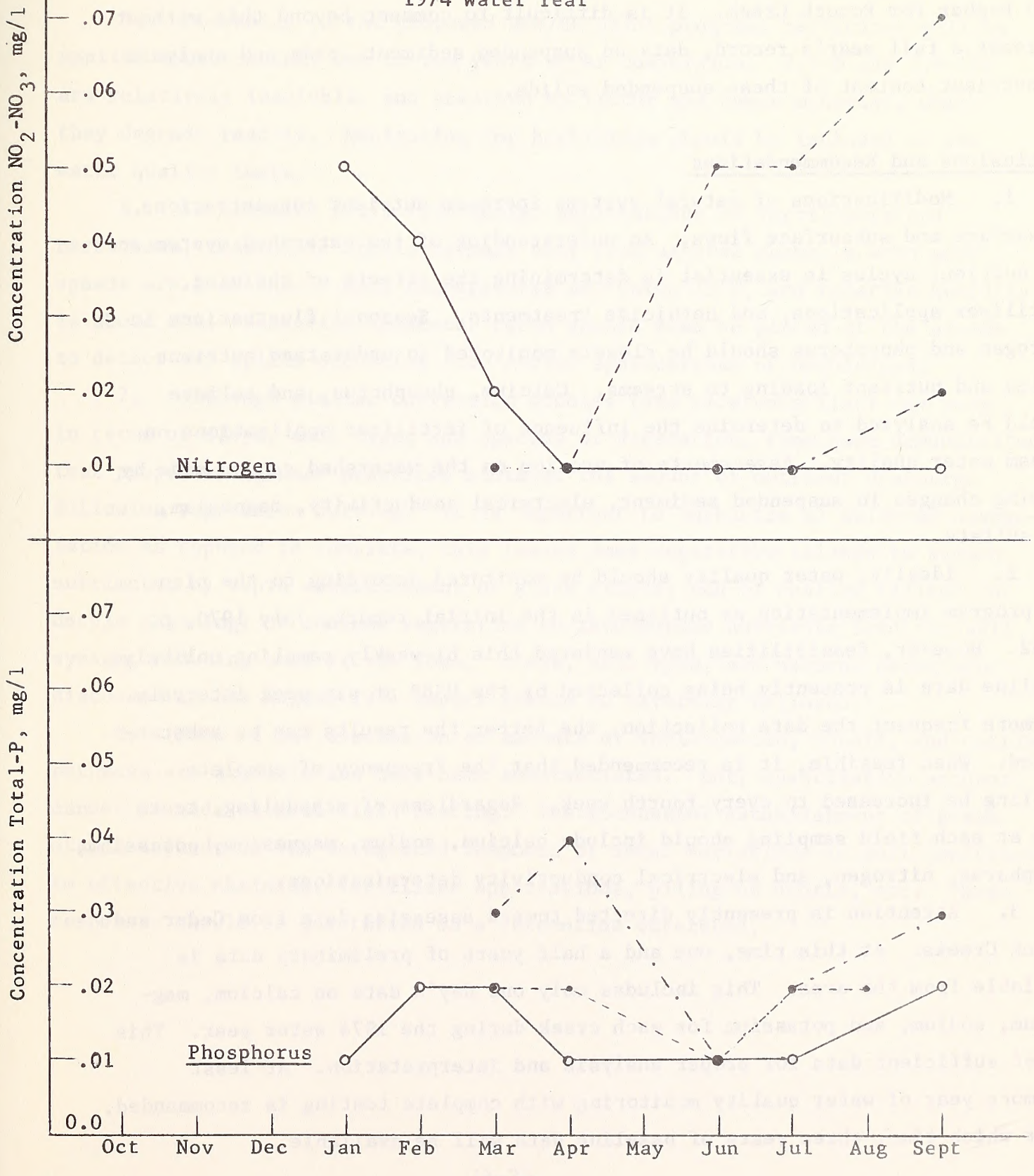
Seasonal Nutrient Fluctuations

at Hunting Creek _____

Cedar Creek - - - - - -

Pocock Creek _ . _ . _ . _

1974 Water Year



of the aerobic stabilization of organic nitrogen, and subsequently occur in polluted waters that have undergone self-purification.

Total phosphorus values refer to all P in the sample regardless of form, primarily including the orthophosphates, hydrolyzable phosphorus, and organic phosphorus. Phosphate values are greater in Pocock Creek than Cedar Creek, which may be due to greater erosion and washout in Pocock. E. C. values are also higher for Pocock Creek. It is difficult to comment beyond this without at least a full year's record, data on suspended sediment loads and analysis of nutrient content of these suspended solids.

Conclusions and Recommendations

1. Modifications of natural systems increase nutrient concentrations in surface and subsurface flows. An understanding of the watershed system and its nutrient cycles is essential in determining the effects of chaining, fertilizer applications, and herbicide treatments. Seasonal fluctuations in nitrogen and phosphorus should be closely monitored to understand nutrient cycles and nutrient loading to streams. Calcium, phosphorus, and sulfate should be analyzed to determine the influence of fertilizer applications on stream water quality. Assessments of erosion on the watershed can be made by viewing changes in suspended sediment, electrical conductivity, magnesium, and sulfate.

2. Ideally, water quality should be monitored according to the plan for program implementation as outlined in the initial report, July 1970, p. IV-52. However, feasibilities have rendered this bi-weekly sampling unlikely. Baseline data is presently being collected by the USBR at six week intervals. The more frequent the data collection, the better the results can be substantiated. When feasible, it is recommended that the frequency of complete sampling be increased to every fourth week. Regardless of scheduling, tests made at each field sampling should include calcium, sodium, magnesium, potassium, phosphorus, nitrogen, and electrical conductivity determinations.

3. Attention is presently directed toward assessing data from Cedar and Pocock Creeks. At this time, one and a half years of preliminary data is available from the area. This includes only one day's data on calcium, magnesium, sodium, and potassium for each creek during the 1974 water year. This is not sufficient data for proper analysis and interpretation. At least one more year of water quality monitoring with complete testing is recommended, after which time, three years of baseline data will be available.

4. Preliminary water quality data for Cedar and Pocock Creeks suggest that Pocock Creek may have a more balanced cycling of nitrogen within the watershed in comparison to Cedar Creek. On the other hand, phosphate values are greater in Pocock Creek than in Cedar Creek. This may be due to greater erosion and washout. Again, data for water years 1975 and 1976 must be analyzed to establish any correlations.

5. According to the proposed BLM/BR pilot program, herbicides will be applied approximately one to two years after conversion. 2,4-D and 2,4-5TP are relatively insoluble, and absorbed by litter and humus material, where they degrade readily. Monitoring for herbicides should be included in the water quality tests.

6. To minimize drift from aerial applications of fertilizers and herbicides, treatments should be made away from natural channels when wind speeds are less than 6 mph, temperatures are below 75°F, and relative humidity is above 30%. Sensitive indicator cards should also be placed at the stream to detect any spills occurring from aerial applications of herbicides.

7. Although similar conversion studies (see reference list) may vary in terms of slope, soil type, and species of vegetation, they have demonstrated that proper management practices minimize the amount of nutrient discharge following vegetation cutting. It is important to emphasize a) selected devegetation as opposed to complete, this leaves some vegetative islands to absorb nutrients; b) rapid establishment of grass stands; and c) shallow tillage (or double chaining) of chained vegetation to incorporate nutrients into the soil system, reducing some of the loss. Slope, soil type, and natural constraints discussed in the August 1974 Report should be carefully followed.

8. Much of the discussion on amounts of infiltration, runoff, and nutrient pathways are academic and have been substantiated. But, quantitative accounts cannot be made without field testing. The successful establishment of grass stands depends on the integrated response of local variations in soil conditions to effective chaining, fertilizer applications, piling of debris, etc. These responses should be quantified on a serpentine watershed.

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SECTION III

AGRONOMIC STUDIES ON THE HENNEKE SOILS OF THE EAST PUTAH CREEK WATERSHED 1974-75

Milton B. Jones

AGRONOMIC STUDIES ON THE HENNEKE SOILS OF THE EAST PUTAH CREEK WATERSHED 1974-75

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INTRODUCTION

Henneke type soil virtually dominates the public lands of the East Putah Creek Watershed (Burgy, 1970). This soil type is derived from parent material of periotite-serpentine rock. The natural vegetation includes shrubs and stunted trees with little or no herbaceous ground cover. It is considered desirable to introduce ground-covering legumes and grasses on some of the gentler slopes to improve water yields, reduce erosion, increase forage production, reduce wildfire fuel, and diversify game habitat. However, serpentine soils are often deficient in nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and molybdenum (Mo) as well as being gravelly and shallow to bed rock (Rai, Simonson and Youngsberg, 1970). Other problems include a high magnesium (Mg) content and possible toxicities to nickel (Ni) and chromium (Cr) (Walker, 1954).

Agronomic studies were undertaken on the serpentine soils of the East Putah Creek Watershed to determine 1) which grassland species would survive and be productive; 2) the fertilizer requirements (what fertilizer should be applied and how much) of grassland species on Henneke soils; and 3) to develop suitable criteria for assessing the fertility status of serpentine soils, especially the calcium status.

ACTIVITIES

Variety Testing

Species were chosen for testing which were known to be adapted to the annual grasslands of northern California and for which seed was commercially available. Emphasis was placed upon testing legumes because the soils are

extremely low in nitrogen. The legumes have the capacity to change atmospheric nitrogen into protein forms. Eventually this nitrogen becomes available to grasses and makes them more productive.

Over a five year period five grasses and 13 legumes were tested in the field.

Grasses: 1) Blando brome; 2) annual rye grass; 3) Harding-grass; 4) Palestine orchardgrass; and 5) Smilo.

Legumes:

Subclover: 1) Woogenellup; 2) Clare; 3) Yarloop; 4) Geraldton; and 5) Dinninup.

Rose clovers: 6) Wilton; 7) Hykon; and 8) Olympus.

Medicagos: 9) Jemalong (173); 10) Barrel medic; and 11) Harbinger barrel medic.

Arrowleaf clover: 12) Amclo.

Woollypod vetch: 13) Lana.

In the spring of 1975 observations made on a legume variety trial planted at site #1 in November 1971 indicated much denser stands and substantially better growth where phosphorus and sulfur fertilizer was applied than on the unfertilized area.

All three rose clover varieties (Hykon, Olympus, Wilton), showed a high degree of stand persistence. Much of this is probably due to their relative earliness and the high percentage of "hard" seed, which is characteristic of the species.

Geraldton and Woogenellup were ranked as the most persistent subclovers while Yarloop and Clare also showed some promise in this respect. Stands of the medic species were poor and variable with only moderate growth. There was no sign of the Lana vetch which had been seeded four years earlier.

Where seedlings were lost due to frost heaving in the establishment year only invading native species and a few soft chess plants were observed. This points out the necessity for adequate establishment before any degree of stand persistence can be obtained. Secondly, soft chess was quite widely distributed throughout the plot indicating the ability of this species to colonize or spread to adjacent areas.

Rose clovers also, but to a lesser degree, spread to other plot areas. Choice of a species whose seed is wind disseminated may offer some real advantages in establishing soil cover.

Twelve range species were tested in the greenhouse to determine their relative requirements for calcium. These species were planted in very calcium deficient soil with from zero to high levels of calcium applied. Phosphorus, potassium, sulfur and molybdenum were applied uniformly to all pots.

If the Ca requirement is defined as the amount of Ca required to give 90% of maximum growth, the following species and varieties had the lowest requirement: Hykon rose clover; four varieties of subclover; Clare, Mt. Barker, Geraldton and Woogenellup; two grasses; soft chess and red brome; and filaree. The medic species required the highest amount of Ca of any species tested.

Based on all the variety tests it was concluded that a mixture of Hykon rose clover, Geraldton subclover and soft chess would be the most satisfactory range species to put in a general seeding on serpentine soils. There are others that may be substituted, depending on the price and availability of seed.

Soil Fertilizer Tests

Serpentine-derived Henneke soil, sampled from 23 sites in the East

Putah Creek Watershed, was tested in the greenhouse and the laboratory to determine which elements were lacking that subclover requires for good growth, and to determine the criteria for soil Ca status.

All the soils were deficient in N, P, and S, and pH ranged from 6.3 to 6.9. When P and S were supplied, subclover yields responded to Ca on 16 of the 23 soils, to Mo on 15 soils, and to K on 8 soils.

Nitrogen concentration in subclover was highest for the P, K, S, Mo treatment and next for the P, K, S, N treatment. Differences among the remaining treatments were relatively small.

Applications of P and S increased these two elements in clover tops from below critical levels to adequate. Potassium levels in the plants indicated that 8 soils were deficient in K.

Yields were correlated positively (though not linearly) to the levels of Ca and the Ca/Mg ratio in the plant and soil. The Ca % in clover tops accounted for 79% of the variation in yield. The Ca/Mg ratio in clover tops accounted for 61% of the yield variability. Exchangeable soil Ca accounted for 67% of yield variability and the ratio exchangeable Ca/Mg accounted for 61%.

The critical level of Ca in subclover tops was 0.61%, and the critical Ca/Mg ratio was 0.43. The critical level of exchangeable Ca was 5.8 meq/100 g soil, and the ratio of exchangeable Ca/Mg had a critical value of 0.23.

Site #1 (near the Red Elephant Mine) was cleared with a brush rake attached onto a bulldozer in the fall of 1970. On October 13 rose clover and Geraldton subclover were each seeded at the rate of 5 lb/A, soft chess and rye grass each were seeded at 4 lb/A, Hardinggrass was seeded at 2 lb/A and Smilo at 1 lb/A. After the seed was broadcast the areas were dragged with a chain to help cover the seed. Seventeen fertilizer treatments were made,

each on a plot 10 by 20 feet. Each treatment was replicated 4 times. The treatments are listed in Table 1. The complete treatment consisted of 100 lb N/A as urea, 100 lb P/A as treble superphosphate, 100 lb K/A as potassium chloride, 130 lb S/A as elemental S, 65 lb Ca/A supplied in the superphosphate, boron (B) as sodium borate, copper (Cu) as copper sulfate, Mo as ammonium molybdate and zinc (Zn) as zinc sulfate.

In June 1972 brush sprouts were sprayed with a back pump with 2,4-D. Certain plots were refertilized in October 1972 as detailed in tables 1 and 2.

Forage yields and percent clover in the forage are given in tables 1 and 2 for the five years of the study. Yields were highly variable from year to year depending upon rainfall distribution and temperatures during the growing season. There was a marked increase in forage growth and a decrease in clover percentage where N was applied (complete compared to the minus N treatment). The effect of N was temporary, lasting only one year on forage production and three years in decreasing clover percentage. There was also a marked increase in forage growth where P was applied (complete compared to the minus P treatment), but not in the first year unless N was also applied. Clover responded in the first year, but it was really the third year before grass yields were increased by applied P in the absence of applied N.

The residual effect of P was good; reapplication of P in 1972 did not significantly improve yields compared to plots receiving P in 1970 only.

Other elements aside from N and P did not have a large enough effect to be significantly different than the plus N and P treatments. Soil tests and color infrared photos indicated that site #1 was an area with adequate Ca.

Table 1. Yield of forage over a five year period as affected by fertilization at the Red Elephant Mine plots (site #1).

	Fertilizer Treatments October 1970	1972	Yield-lb/acre 1971	1972	1973	1974	1975	ΣX 5 yrs.*	ΣX 3 yrs.**
1.	Complete		3,990	420	1,840	680	850	7,780	3,370
2.	-N		160	330	2,300	500	770	4,060	3,570
3.	-P		280	220	750	350	370	1,970	1,470
4.	-K		3,210	420	2,220	510	1,240	7,600	3,970
5.	-S		2,540	520	2,020	810	1,130	7,020	3,960
6.	-Ca		3,540	320	1,680	730	1,070	7,340	3,480
7.	-N, -P		110	210	500	370	440	1,630	1,310
8.	-N, -K		240	280	2,110	620	800	4,050	3,530
9.	-N, -S		490	360	1,850	660	700	4,060	3,210
10.	-N, - Micro	+N	250	320	4,460	370	540	5,940	5,370
11.	-N, -B	+P	220	460	2,710	680	800	4,870	4,190
12.	-N, -Cu	+S	380	350	2,020	630	850	4,230	3,500
13.	-N, -Mo	+NP	170	270	4,740	340	570	6,090	5,650
14.	-N, -Zn	+NS	160	410	4,640	360	610	6,180	5,610
15.	-N, +10Ca	+PS	210	260	1,960	650	760	3,840	3,280
16.	-N, +2K	+NPS	330	310	4,940	220	560	6,360	5,720
17.	Check	Check	100	170	720	390	350	1,730	1,460
LSD (.05)***			728	200	920	270	342	220	290

*Cummulative yield for five years.

**Cumulative yield for last three years.

***Least significant difference at the 5% level.

Table 2. Percent clover over a five year period as affected by fertilization at the Red Elephant Mine plots (site #1).

Fertilizer treatment October 1970	1972	1971	1972	1973	1974	1975	$\bar{x}$ 5yrs*	$\bar{x}$ 3 yrs**
1. Complete		8	4	18	25	12	13	18
2. -N		53	14	53	26	14	32	31
3. -P		8	1	3	4	1	3	3
4. -K		9	11	10	24	14	14	16
5. -S		18	14	23	40	16	22	26
6. -Ca		11	9	30	38	19	21	29
7. -N, -P		13	3	3	2	1	5	2
8. -N, -K		53	15	30	25	14	27	23
9. -N, -S		65	18	60	35	15	39	37
10. -N, -Micro	+N	45	11	1	11	6		6
11. -N, -B	+P	60	13	50	26	19		32
12. -N, -Cu	+S	68	18	73	35	19		42
13. -N, -Mo	+NP	35	7	1	10	5		5
14. -N, -Zn	+NS	48	8	2	14	6		7
15. -N, +Ca	+PS	55	14	58	25	11		31
16. -N, +2K	+NPS	48	10	1	10	6		6
17. Check	Check	18	1	6	7	4		6
LSD (.05)***		24	10	17	16	9	8	8

*5 year mean.

**Mean for last three years.

***Least significant difference at the 5% level.

Forage growth was mowed and removed from site #1 each year except 1973 when it was burned to control brush seedlings and sprouts. The brush control program on this plot area has been quite effective except on unfertilized check plots where there was not enough fuel to carry a hot fire and brush seedlings were not destroyed. This is particularly true in the case of cypress seedlings which 2,4-D does not kill.

In October 1972 a thirty-acre area at site #2 (near Jerusalem Valley) was chained and seeded with range clovers and grasses. Three fertilizer treatments, check, 16-20-0-15 (16% N, 20% P_2O_5, 0% K_2O and 15% S) and singlesuperphosphate (0-20-0-12) were applied in three replications. Superphosphate also contains 20% Ca. It was evident during that season that the clover seed had not been properly inoculated because the only place it grew well was where nitrogen fertilizer had been applied. In October 1973 newly inoculated clover seed was drilled in a strip parallel to the road and across three fertilizer treatments.

On April 8, 1975, square foot frames were dropped into each of the treatments 75 times (25 in each replication). The percent of the ground covered by vegetation was estimated and the presence of clovers and grasses within the frame was recorded. Results are found in table 3 and indicate the effect of fertilization in increasing vegetative ground cover. At this point in time the 16-20-0-15 appeared to have no advantage over the single-superphosphate. The importance of proper inoculation of clover seed may also be demonstrated by comparing the percentage of square feet having rose and subclover in inoculated and uninoculated treatments.

Calcium and phosphorus rate trials were established in October 1974 at sites 3-A, 3-B and 3-C (near Cedar Creek) and site 5 (on Dunnigan Hill) selected for their differences in vegetative composition prior to clearing.

Table 3. Percent of square foot frames in which the species listed occurred April 8, 1975, on the site #2 clearing.

	Sown with uninoculated seed, October 1972			Sown with inoculated seed, October 1973		
Fertilizer	Ck	SSP	16-20	Ck	SSP	16-20
Rose clover	3	1	1	8	55	68
Subclover	0	1	3	32	72	55
Soft chess	64	99	96	67	97	96
Orchardgrass	1	11	0	7	1	0
Hardinggrass	3	8	3	7	7	4
Red brome	0	3	3	1	5	7
Fescue	15	5	15	5	3	19
% ground cover	12	45	58	14	52	52

Paired plots testing both elements at sites 3-A and 3-B and Ca trials at sites 3-C and 5 were established. Some characteristics of the soil from these are given in Appendix A. All plots were sown to a mixture of equal amounts of Wilton rose clover, Geraldton subclover and Blando brome at a rate of 100 lb/A. All plots received a basal application of 125 lb/A K and 0.25 lb/A Mo. The Ca basal rate on the P experiment was 1000 lb/A and the P basal rate on the Ca trial was 200 lb/A. Calcium treatments in the test were 0, 125, 250, 500, 1000, 2000, 3000, 4000, and 6000 lb/A. Phosphorus treatments were 0, 12, 25, 50, 100, 150, 200, 300 and 400 lb/A. Each treatment was replicated twice at each site except the check, which had four replicates. All three sites showed marked differences in their response to applied Ca. The amounts of Ca required to increase yields to 90% of maximum were 500, 300 and 3800 lb/A for sites 3-A, 3-B and site 5, respectively. However, applying a relatively small amount to sites 3-B and site 5 had a very marked effect. For example, 250 lb/A Ca increased yields to 57% and 45% of maximum, respectively. Without applied Ca, relative yields were 27% and 12% of maximum.

Site 3-A showed relatively small response to added P with a P requirement of about 25 lb/A. It also had a much lower level of productivity than site 3-B, which had a P requirement of about 50 lb/A (500 lb superphosphate/A).

In earlier tests on six serpentine soils from the East Putah Creek Watershed the average P requirement was estimated at about 500 pounds singlesuperphosphate per acre (Jones, 1974).

Assays for Determining Mineral Status

1. Plant analysis: Chemical analysis have been run on a large number of plant samples obtained from the field and from greenhouse material. Twenty-one elements were determined on clover and native brush samples by emission spectroscopy at UCLA through the cooperation of A. Wallace and O. R. Lunt (Appendix B). These data, reported as ranges of values, indicate possible deficient and toxic levels. The native brush species leaves were higher in Ca and lower in Mg, Ni and Cr than clovers. Apparently the native plants are able to absorb higher levels of Ca from a deficient soil and screen out possible toxic elements better than subclover. One of the function of Ca in plant physiology is to ameliorate toxic effects of various metals (Jones and Lunt, 1967).

The effect of Ca applications to a deficient soil in the greenhouse upon the yield of subclover and the concentration of Ca, Mg, Ni and Cr in different plant parts was measured (Appendix C). Applied Ca increased yield and Ca concentration in clover parts and decreased Mg in new leaves and stems. The effect on old leaves was not clear since there was not sufficient plant material for analysis at the zero and 200 ppm Ca level. Applied Ca reduced Ni levels in new leaves in clover where 400 ppm or more Ca was applied. Applying 1600 and 3200 ppm Ca increased Ni in old leaves when compared to the 400 and 800 ppm treatments. Data is not yet available for Ni levels in stems.

The Cr level was decreased by applied Ca in new leaves and stems, and increased in old leaves.

2. Soil Analysis: Pertinate soil test data thus far completed on field test sites for 1974-75 are given in Appendix A. Values from the Cedar Creek area are marginally low in Ca and Ca/Mg ratios are low, indicating a need for additional Ca. The values comparing samples taken from bare ground and under brush cover are of particular interest, indicating that where the sample is taken in relationship to standing vegetation is important. Apparently the leaf drop from native shrubs is enough to increase the soil test values.

3. Relationship of Soil Spectral Irradiance to Exchangeable Ca: In May and June 1973, color infrared and Ektachrome aerial photos were taken of sites #1 and 2 by Dr. W. Wildman.

It was observed that sites which had soils testing low in exchangeable Ca appeared almost white on the color infrared photos, whereas soils high in Ca appeared greenish in color. Differences were not so apparent on the Ektachrome slides.

The color infrared slides taken by W. Wildman were projected on a screen and the number of foot candles reaching the screen were measured near the site sampled and in the area disturbed by sampling. The amount of light reaching the screen through the color infrared slides was negatively correlated with exchangeable Ca levels in the soil. The light meter reading accounted for 68% of the variation in soil exchangeable Ca. Direct soil reflectance in the field accounted for 73% of the variation in calcium.

Soil reflectance or color infrared photography may have some value in deliniating calcium deficient areas. One of the main problems in putting this method to practical use is the interference of vegetation with soil reflectance. Variation in soil reflectance shows up very clearly on cleared land.

Survey of Cedar and Pocock Creek Watersheds (site #4)

Soils in the Pocock and Cedar Creek Watersheds vary considerably with important consequences to introduced species. Knowledge of the nutrient status (especially Ca) of particular areas would be of value in deciding both where to plan conversions and how much fertilizer to apply. The native vegetation in these two watersheds also varies considerably. If relationships between the native vegetation and the nutrient status of the soils could be found, a convenient, inexpensive means of obtaining some idea of the fertility of the soils would be available.

Forty sites have been chosen randomly within areas mapped out as suitable for conversion to the two watersheds. Permanent plots 15m x 15m have been laid out and soil samples taken within each plot. Soil samples for chemical analysis were taken along each of 3 transects at each site. Each sample consisted of 2 subsamples taken along the transect. Separate samples were taken for the A and B horizons (surface and subsurface soil, respectively). One of the subsampling sites was chosen for collecting separate samples of the A and B horizons for physical analysis. The chemical analysis for the major cations is completed.

Exchangeable sodium levels ranged from 0.59 to 1.33 (all concentrations are expressed in meq/100 g) with the overall average being 0.96. There is no difference between soil horizons, but there are significant differences among the sites.

Exchangeable potassium showed a highly significant difference due to horizons. Values in the A horizon range from 0.58 to 1.56 meq/100 g with an average of 0.98 compared to a range of 0.38 to 1.18 in the B horizon and an average of 0.66. All but 2 sites had a significantly higher level of K in the A horizon. Differences among sites were also highly significant.

The average exchangeable Ca values at each site are shown in Appendix D. A map with the approximate location of each site is in Appendix F. Levels in the A horizon range from 3.04 to 13.43 meq/100 g soil, with an average of 7.10, and in the B horizion they range from 0.54 to 13.31 with an average of 3.95. Differences due to horizon are highly significant. At only one site in Pocock Creek is Ca greater in the B horizon than the A. There are four other cases where the differences are not significant. There are significant differences among sites, and in Pocock Creek there is a significant effect due to the position on the slope. Samples taken from the upper portion of the site average less than those from the lower end. This does not hold in Cedar Creek where the average for the upper samples exceeds that for the lower samples, though not significantly.

The presence of cypress on a site appears to be related to low calcium in the subsoil (B-horizon), but unrelated to calcium level in the surface (A-horizon).

Soil horizon is also a significant factor affecting Mg levels (Appendix E). In this case, however, concentrations are greater in the B horizon. In the two watersheds 24 sites have significantly more Mg in the B horizons than in the A. Eleven sites have more in the A than in the B but only three are significantly greater. Values range from 10.49 to 43.21 meq/100 g soil in the A horizon with an average of 23.39 and from 9.54 to 69.96 in the B with an average of 29.75. Differences among sites are also highly significant. There is a tendency for Mg levels to be higher in cypress stands than in non-cypress stands. Ten of 18 cypress stands have Mg levels exceeding the average. This it true for A and B horizons. Only 8 and 9 of 22 non-cypress stands have Mg levels exceeding the average for the A and B horizons, respectively.

SUMMARY AND RECOMMENDATIONS

Annual grassland species were successfully established on serpentine soils following clearing of brush with a brush rake on a bulldozer blade or by pulling a modified anchorchain twice over the brush. The annual grasses and clovers must be covered with 1/8 to 1/4 inch of soil. This usually was done with the second pass of the anchorchain.

Clover seeds must be inoculated with effective nitrogen fixing rhizobium since there appears to be no such bacteria in native serpentine soils.

Adequate amounts of phosphorus must be applied to obtain satisfactory growth of planted species. Benefits will also be seen from applying some nitrogen the first year, but it is not recommended due to high costs and leaching losses. Sulfur, molybdenum and potassium may also be low. Calcium varies from extremely deficient to adequate. Singlesuperphosphate is probably the most satisfactory fertilizer because it supplied 20% phosphate, 12% sulfur and 15% calcium. About 500 pounds of this fertilizer are recommended to meet the phosphorus requirements for at least 5 years (since that is the time we have measured responses) and perhaps longer. This amount will also fill the sulfur requirements, and in some instances the calcium needs. However, there are many areas where additional calcium should be applied. An example of general seeding and recommended fertilization with costs as of 1975 are shown in table 4. To determine whether such costs could be recovered by the increased water yield following conversion is the major objective in running a pilot clearing project of such size that changes in water yield and quality could be measured.

In order to summarize the effects of such a brush to grass conversion program the following is an evaluation of the 40 acres cleared, seeded and fertilized in October 1974.

Table 4. Projected cost of a conversion of brushland to grassland with prices as of summer 1975.

A.	Seed	Lbs/A	Cost/lb	Cost/A
	Blando brome	8	$ 1.05	$ 8.40
	Rose clover	6	1.05	6.30
	Geraldton subclover	6	1.05	6.30
B.	Double chaining			14.00
C.	Fertilizer		Cost/ton	
	Singlesuperphosphate	500	$120.00	30.00
	Gypsum	1000	62.00	31.00
D.	Seed application	20		3.00
E.	Fertilizer application			
	Singlesuperphosphate	500		12.00
	Gypsum	1000		24.00
F.	Contingencies	Approx. 10%		
			TOTAL	$135.00
	Maintenance			
	Spring 1976 - Herbicide			$ 20.00
	Spring 1978 - Herbicide			$ 20.00

There was a good to excellent stand of seeded species on about 50% of the 40-acre clearing at site #3 as of June 1975. The west end (or lower end) generally was better than the east end, but there were good stands and bare areas on every elevation, slope, aspect and soil type.

There appeared to be four factors that contributed to poor stands. The distribution of seed and fertilizer by the helicopter are two of the reasons and could be remedied by greater care. The flight lines for both seed and fertilizer distribution were clearly visable in many places. Where seed was applied but no fertilizer, plants were very small with only one seed head per plant. Heavy use by wildlife is another factor that greatly reduced the stand in some areas. Proof of this can be seen on the inoculation and fertility plots where good plant growth can be seen inside the cages and practically no plants on the plots outside the cages. Snow and frost heaving also accounted for the loss of some seedlings during the early winter period.

Soft chess grass and rose and subterranean clover will grow and be productive on the serpentine soils of the cleared area near Cedar Creek if properly inoculated, sown and fertilized. If any of the steps are omitted or done poorly, failure will occur.

Observations on sites #1 and #2 confirms the findings of herbicide workers in the University of California (Al Murphy, personal communication) that: 1) Ground applications are much more effective than air applications; 2) May is a better time to apply 2,4-D to brush than June (depending on year and soil moisture at the site); and 3) It is better to spray first year sprouts than sprouts two years old. Without the control of brush regrowth, a cleared site will most likely be back to its original condition within a few years.

Where chamise and leather oak are sprouting back, herbicide sprays should be applied the first year after clearing and follow-up sprays should be applied each year thereafter until desired control has been achieved.

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Appendix A

Some chemical characteristics of soil samples representing several serpentine sites.

Site	$NaHCO_3$-P	Exchangeable Ca	Exchangeable Mg	Ca/Mg	Ni
	ppm	meq/100 g			ppm
3-A		3.64	17.71	0.20	10.0
3-B		4.29	14.81	0.29	9.8
3-C		3.84	13.85	0.28	9.0
Bare soil* (near 3-A)	4.8	3.03	11.32	0.28	17.6
Brush covered soil* (near 3-A)	4.3	5.02	14.95	0.36	18.3
5		0.90	8.64	0.10	11.4

*Values for bare and brush covered sites represents the means of six separate sites; exchangeable Ca and Mg values are significant at the 10% level, but Ni values are not significantly different.

Appendix B

Ranges in concentrations of 21 elements in subclover grown on serpentine soils from 18 sites, and ranges for 12 elements in native brush leaves sampled from the 23 sites.

	Range in Concentration			
	Subclover*		Native brush leaves	
	Low	High	Low	High
P	0.062	0.118%	0.02	0.25%
Na	0.025	1.058%		
K	1.03	1.83%	0.19	1.01%
Ca	0.10	1.20%	0.26	1.60%
Mg	0.70	3.00%	0.19	.57%
Zn	19	105 ppm	17	73 ppm
Cu	1	12 ppm	1	5 ppm
Fe	188	4338 ppm	23	2069 ppm
Mn	47	314 ppm	8	73 ppm
B	13	110 ppm		
Al	60	1216 ppm	9	245 ppm
Si	0.10	1.35 ppm		
Co	2	13 ppm	1	2 ppm
Ni	5	488 ppm	< 2	40 ppm
Mo	0.2	2.9 ppm		
Cr	9	51 ppm	< 0.2	10 ppm
Sr	6	54 ppm		
Ba	3	22 ppm		
Li	0	2 ppm		
Sn	0.1	7 ppm		
Pb	0.5	21 ppm		

*Ranges in subclover do not include values from clover fertilized with the element in question.

Appendix C

Effect of increasing Ca applications on subclover yield and concentrations of Ca, Mg, Ni and Cr in the clover growing on a Ca deficient serpentine soil near Cedar Creek.

Applied Ca ppm	Subclover yield g/pot	%Ca	%Mg	ppm Ni	ppm Cr
			New leaves		
0	0.24	0.22	1.05	167	14
200	0.66	0.32	1.20	201	12
400	1.56	0.30	0.67	122	9
800	5.70	0.35	0.50	120	8
1600	6.58	0.56	0.52	117	7
3200	6.66	0.74	0.48	131	8
LSD (0.05)*	0.36	.07	0.13	49	3
			Old leaves		
400		0.42	1.20	172	8
800		0.68	1.05	131	7
1600		1.13	1.17	454	17
3200		1.74	1.25	421	16
LSD (.05)*		.07	0.13	39	5
			Stems		
0		0.27	2.16		0.28
200		0.22	1.24		0.38
400		0.28	1.14		0.55
800		0.31	0.78		0.11
1600		0.36	0.74		0.05
3200		0.44	0.84		0.07
LSD (.05)		.07	0.13		0.24

*Least significant difference at the 5% level.

Appendix D

Exchangeable calcium (meq/100 g soil) for the A and B horizons in the 40 sampling sites in Pocock and Cedar Creeks.

	Pocock Creek			Cedar Creek	
Site #	A horizon	B horizon	Site #	A horizon	B horizon
1	10.57**	4.99	21	5.78	4.20
2	6.66	3.45	22	5.91	4.66
3	7.40	7.11	23	3.82	3.20
4	13.43	13.31	24*	6.11	0.75
5	6.78	4.37	25*	4.03	1.00
6	3.74	2.53	26*	3.04	0.54
7*	6.94	3.41	27*	11.65	4.70
8*	4.87	1.62	28*	4.32	2.04
9	6.86	4.32	29*	3.95	1.29
10*	9.73	3.78	30*	8.78	4.66
11*	12.31	3.87	31	6.53	4.83
12*	5.74	1.50	32*	7.15	2.91
13*	6.45	2.16	33*	6.28	2.29
14	5.86	4.32	34	4.70	3.12
15	6.73	3.62	35	7.99	7.36
16	4.62	6.65	36*	10.60	4.62
17	6.70	5.45	37*	7.40	1.96
18	8.69	5.99	38	6.24	2.58
19*	11.61	3.99	39	7.15	4.00
20	10.27	5.28	40	6.57	5.32
$\bar{X}$	7.80	4.59		6.40	3.30

*Indicates cypress site.

**Averages for 3 samples.

Appendix E

Exchangeable Mg (meq/100 g soil) for the A and B horizons in the 40 sampling sites in Pocock and Cedar Creeks.

Site #	Pocock Creek A Horizon	Pocock Creek B Horizon	Site #	Cedar Creek A Horizon	Cedar Creek B Horizon
1	24.96**	22.77	21	33.47	69.96
2	22.30	22.22	22	30.18	32.51
3	23.05	30.73	23	10.49	16.18
4	18.65	21.12	24*	12.00	38.13
5	22.01	34.84	25*	22.63	45.95
6	30.04	36.35	26*	43.21	38.96
7*	24.01	31.55	27*	13.93	9.54
8*	30.04	28.80	28*	13.72	22.91
9	16.53	24.83	29*	23.25	54.18
10*	23.32	36.21	30*	25.38	24.96
11*	26.48	28.94	31	31.27	28.94
12*	28.67	34.57	32*	23.05	21.53
13*	24.83	36.21	33*	35.25	38.96
14	23.16	27.44	34	18.79	24.14
15	25.26	25.24	35	16.46	14.26
16	23.32	30.32	36*	19.07	19.34
17	31.41	35.80	37*	26.06	31.83
18	16.73	20.85	38	12.21	18.93
19*	32.51	24.55	39	10.56	22.36
20	24.01	32.51	40	23.04	33.74
$\bar{X}$	24.57	29.29		22.20	30.37

*Indicates cypress site.

**Averages for 3 samples.

SECTION IV

THE MACROINVERTEBRATE FAUNA OF CEDAR CREEK, NAPA COUNTY, CALIFORNIA

C. A. Siegfried

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THE MACROINVERTEBRATE FAUNA OF CEDAR CREEK, NAPA COUNTY, CALIFORNIA

C. A. Siegfried and A. W. Knight[1/]

INTRODUCTION

Hydrobiological investigations conducted from February 1971 to the present have been designed to obtain baseline information for the assessment of the possible impact of vegetation conversion on the macrobenthic communities of the streams within the East Putah Creek Watershed. Much of our effort has been focused on the possible impact of increased sedimentation within the streams. Although constraints will be imposed to minimize the risk, increased runoff from proposed vegetation conversion projects may be accompanied by greater sediment loads and increased sediment deposition within the streams of the watershed. Fine sediments in these streams could alter the productivity and species composition of the macrobenthic communities.

HYDROBIOLOGICAL STUDIES (February 1971-August 1974)

The initial phase of the investigations (February 1971-June 1972) involved surveys of the streams of the watershed to determine macrobenthos species composition and relative abundance. The streams surveyed included Hunting, Putah, Eticuera, and Nevada Creeks. The result of these surveys (appendix tables A-D) suggested that benthic diversity was a function of substrate and flow stability. Streams or stream reaches with rocky, stable substrata and/or permanent flow exhibited greater benthic diversity than those with shifting, unstable substrata and/or intermittent flow.

The results of quantitative sampling during 1973 support the conclusion that, as fine sediment becomes an increasingly large component of the substrate, benthic diversity declines. Average diversity values for stations within Eticuera Creek, when arranged in order of decreasing value, reflect the amounts of fine sediment present at each station. Highest diversity occurs at those stations with the least proportion of fine sediment and lowest diversity occurs

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at stations with the largest proportion of fine sediments. Diversity values from the other streams of the watershed also reflect this relationship.

Laboratory investigations were undertaken concurrent to the quantitative sampling program to determine the reaction of selected macroinvertebrates to increased sedimentation.

One series of studies was designed to measure changes in drift, the passive transport of macrobenthos via water currents, induced by sedimentation. Gammon (1970) linked increases in drift rates to increases in suspended sediment concentrations, indicating that increased drift can be used as an indicator of stress in aquatic organisms. Drift in the laboratory streams exposed to sedimentation was consistently higher than that in clear streams. Additional observations during the course of the study suggest that the higher drift rates reflected stress in those organisms exposed to sedimentation. Our test organism showed a strong avoidance reaction to sediments. Many individuals crawled out of the water in their attempts to avoid exposure to fine sediment. Recovery of test organisms from the clear streams, after termination of the study, was 100%, while recovery in the sedimented stream was 67%, reflecting losses as a result of avoidance and death.

Additional studies showed drift of "clean-water" invertebrates to be lowest on "normal" cobble and gravel substrates and increase as the proportion of fine substrate particles increased. This increase in drift can be interpreted as a manifestation of stress induced by unfavorable substrates. Stress in aquatic organisms will also be reflected in lower growth rates, survival and reproductive success.

During the 1974 phase of our hydrobiological investigation a "substrate-preference index" was developed to aid in the determination of the sensitivity of various stream habitats to perturbation by increased sedimentation. Quantitative benthic sampling and the substrate-preference determinations were utilized to derive a quantitative index to characterize the stream communities in relation to substrate preference. This index allows one to characterize the macrobenthic communities of different habitats within a stream as well as different streams. The index provides a rough indication of the sensitivity of these communities to the additional deposition of fine sediments (see Siegfried and Knight, 1974).

During 1974 the Cedar Creek watershed was selected for a demonstration site. Faunal surveys and quantitative benthic sampling were initiated and continued through 1975.

HYDROBIOLOGICAL STUDIES (August 1974-June 1975)

Hydrobiologic work for the year 1974-75 involved monitoring of the benthic community of Cedar Creek, Napa County, California (T11N;R5W;S25), to obtain baseline information for the assessment of the effects of limited vegetation conversion in the Cedar Creek watershed. Following guidelines established earlier (Burgy, 1973), test areas were set up in late 1974 partially in the Cedar Creek and Pocock Creek watersheds. Only Cedar Creek was monitored, but plans are considered to include Pocock Creek in 1975-76.

Study Site

Cedar Creek, about 15.0 km (9 miles) north of Lake Berryessa, is a typical semipermanent foothill stream. It originates from ground seepage at about the 740-m (2100 ft) level and flows northwest through chaparral for about 5.8 km (3.5 miles) to its confluence with Hunting Creek. Three monitoring stations were selected on Cedar Creek near the vegetation conversion test plots. (About 5% of test site 3 is included in the Cedar Creek drainage.) The monitoring stations are described below (Fig. 1):

Station 1. About 10 m upstream from Cedar-Pocock Creek Road; substrate of bedrock overlain with thin layer of fine-coarse gravel and some cobble-sized particles; current velocity and water level generally low.

Stations 2-3. Each collecting site 15-30 m below entrance of arroyos into Cedar Creek Canyon; arroyos draining general area of test site; substrata of sparse cobble on bedrock; moderate to low current velocities and water levels.

There was no evidence of sedimentation at any of the monitoring stations.

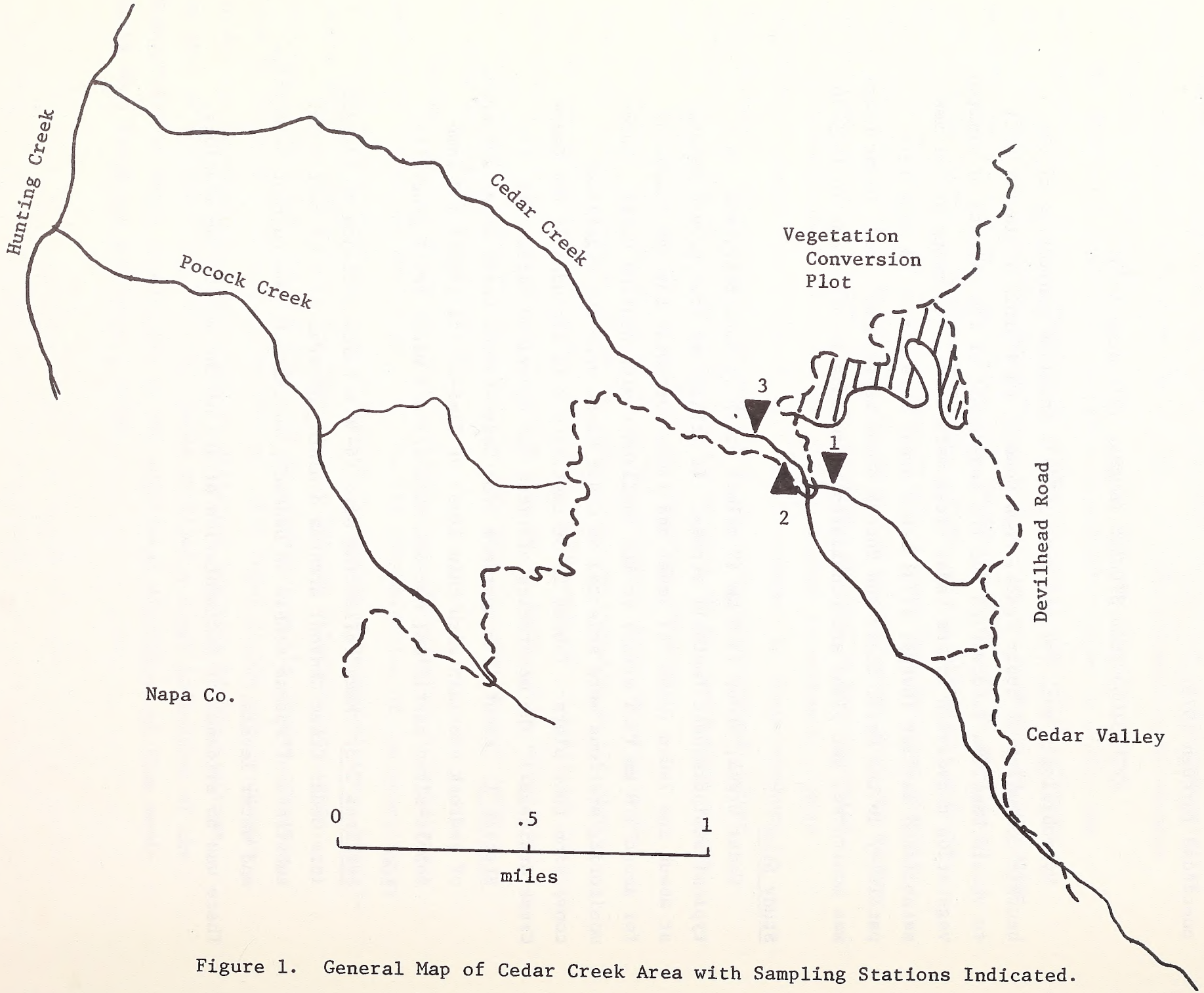

Figure 1. General Map of Cedar Creek Area with Sampling Stations Indicated.

Methods

Quantitative samples of the benthic communities of Cedar Creek were obtained with a Surber square-foot sampler (net of 0.5-mm mesh). Three samples were collected at randomly selected sites at each station in each of four months, January, March, April and May of 1975. The sampler was placed firmly on the stream bed, and all stones greater than 5 cm in diameter were rubbed clean at the mouth of the net. Small stones and loose gravel within the sample area were stirred and rubbed together at the opening of the net until only clean gravel remained. The contents of the net were transferred to a collection jar and preserved in ethanol.

Benthic samples were sorted by hand with a Bausch and Lomb binocular dissecting microscope, and each organism was identified to the lowest possible taxon. Identification was often limited to the generic or family level because of the incomplete state of knowledge on the taxonomy of many groups of immature aquatic insects. Because the procedures would be laborious and time-consuming, no attempt was made to identify chironomid larvae beyond the family level.

To assess relative similarities between the biotic assemblages of the various sampling stations, a coefficient of similarity was calculated with the Jaccard equation:

$$C_s = \frac{j}{a+b-j}$$

where C_s = coefficient of similarity expressed as a percent, j = the number of species common to both assemblages, and a and b are the number of species present at each station. Values exceeding 50% suggest that the two assemblages being compared generally include the same species (Langford and Daffern, 1975). Although this method of comparing catches exaggerates the importance of the rarer species it provides an objective, quantitative comparison of species lists derived from benthic surveys.

Community structure at each station was assessed by calculating diversity after Wilhm (1972).

$$\bar{d} = - \Sigma \, (n_i/n \log_2 n_i/n)$$

where n_i is the number of individuals belonging to the i'th species, and n is the total number of individuals in the collection. Diversity values

exceeding 3 are generally characteristic of clean water communities, i.e., healthy, balanced communities. Values less than 1 indicate heavy pollution, and values of 1 to 3 represent intermediate conditions (Wilhm, 1972).

Results and Discussion

The macrobenthic fauna of Cedar Creek is quite diverse in the study area. Ten orders of aquatic insects are represented by forty-one families and sixty-six species or species complexes (Table 1). The fauna was generally dominated by one or more of the following orders: Diptera, Plecoptera, Ephemeroptera, Trichoptera, and/or Coleoptera. Similarity coefficients indicate that the assemblages of organisms collected from Stations 2 and 3 were quite similar each month (Fig. 2). Such similarity would be expected because physical conditions are similar at each site and they are close together. The fauna collected at Station 1 had little in common with that at Stations 2-3, primarily because the habitats at Station 1 differed from the others.

The January samples were dominated by Plecoptera (Capnia) and Diptera (Chironomidae) at Station 1 and by Trichoptera (Hydropsyche and Micrasema) and Diptera at Stations 2 and 3 (Chironomidae) (Appendix Table E). Samples collected in March, following heavy rains of January through early March, reflect a shift in dominance at Stations 2-3, to Ephemeropterans (Baetis, Ephemerella) and Coleopterans (Ordobrevia), groups less susceptible to displacement by the scouring action accompanying periods of high water.

The change in species composition at all stations following the months of heavy rainfall is reflected in coefficients of similarity between assemblages present at each station in successive collections. At all stations the coefficient of similarity between January and March collections was less than 50%, indicating relatively little similarity between species assemblages present in the two months (Fig. 3). Station 1 shows little similarity between successive collections, primarily because of immigration and hatching of additional species, while the fauna at Stations 2 and 3 remains fairly consistant (C_s > 50%).

High water accompanying the heavy rains of January-March reduced total numbers of species and benthic standing crops at all stations (Table 2). Station 1 had the lowest numbers of species and standing crops each month, while Station 3 had the highest. As a consequence of washouts, each station lost about 25-33% of the species present in January. Reductions in benthic standing crop were even more spectacular. The standing crop at Station 1

Table 1

January 1975-May 1975

Ephemeroptera (Mayflies)
- Baetidae
  - *Baetis* spp.
- Leptophlebiidae
  - *Paraleptophebia* sp.
- Tricoxythodidae
  - *Tricorythodes fallax*
- Heptageniidae
  - *Epeorus* (*Ironopsis*)
  - *Epeorus* (*Iron*)
- Siphlonuridae
  - *Ameletus* sp.
- Ephemerellidae
  - *Ephemerella* (*Invaria*)

Odonata (Damselflies and Dragonflies)
- Coenagrionidae
  - *Argia moesta*
- Gomphidae
  - *Octogomphus specularis*

Plecoptera (Stoneflies)
- Nemouridae
  - *Capnia* sp.
  - *Nemoura* (*Malenka*) sp.
  - *Brachyptera* sp.
- Chloroperlidae
  - *Alloperla* spp.
- Perlodidae
  - *Isogenus* sp.
- Perlidae
  - *Acroneuria californica*

Hemiptera (True bugs)
- Saldidae
- Belostomatidae
  - *Belostoma* sp.

Megaloptera (hellgrammites)
- Corydalidae
  - *Neohermes californicus*

Trichoptera (Caddisflies)
- Philopotamidae
  - *Wormaldia* sp.
- Psychomyidae
  - *Tinodes*
- Hydropsychidae
  - *Hydropsyche*
  - *Cheumatopsyche*
- Rhyacophilidae
  - *Rhyacophila acropedes*
  - *R. vocala*
  - *R. vaccua*
- Hydroptilidae
  - *Oxyethira pallida*
  - *Agraylea saltesea*
- Limnephilidae
  - *Neophylax* sp.
  - *Ecclisomyia* sp.
  - *Neothremma genella*
- Leptoceridae
  - *Oecetis* sp.
- Lepidostomatidae
  - *Lepidostoma* sp.
- Brachycentridae
  - *Micrasema* sp.
- Glossosomatidae
  - *Glossosoma* sp.

Lepidoptera (Moths and Butterflies)
- Pyralidae
  - *Parargyractis* sp.

Coleoptera (Beetles)
- Dytiscidae
  - *Deronectes* sp.
- Elmidae
  - *Zaitzevia* sp.
  - *Cleptelmis* sp.
  - *Ordobrevia* sp.
- Halipidae
  - *Peltodytes* sp.
- Psephenidae
  - *Eubrianx edwardsi*

Diptera (Flies)
- Tipulidae
  - *Hexatoma* sp.
  - *Limnophila* sp.
  - *Dicranota* sp.
  - *Antocha monticola*
  - *Eriocera* sp.
- Blepharoceridae
  - *Bibiocephala* sp.
- Psychodidae
  - *Maruina* sp.
- Chironomidae
  - *Calopsectra* sp.
  - *Cardiocladius* sp.
  - *Brillia* sp.
  - *Tribelos* sp.
  - Tanypodinae
  - undet. Orthocladinae
  - undet. Chironominae

Table 1 Continued

Simulidae
Prosimulium sp.
Dixidae
Dixa (*Meringodixa*) sp.
Stratiomyidae
Euparyphus sp.
Empididae
Ephydridae
Ceratopogonidae
Bezzia sp.

Miscellaneous groups
Collembola (springtails)
Turbellaria (planarians)
Oligochaeta (earthworms)
Acarina (mites)
Anura (tadpoles)

Table 2

Species Number(s), Standing Crop Per Square Meter (n), and Diversity ($\bar{d}$), at Each Cedar Creek Collection Station, January-May 1975.

Sta.	January 1975			March 1975			April 1975			May 1975		
	s	n	$\bar{d}$	s	n	$\bar{d}$	s	n	$\bar{d}$	s	n	$\bar{d}$
1	12	219	2.64	8	129	2.39	10	215	2.10	18	477	2.16
2	32	3570	3.21	23	334	3.66	21	642	3.40	23	983	3.31
3	37	4162	2.89	28	495	3.99	29	872	3.70	28	1270	3.53

was reduced to about 59% of January levels. Stations 2 and 3, with a larger watershed and therefore greater fluctuations in water level accompanying rainfall, suffered reductions to 9% and 12% of January levels.

Considerable evidence indicates that periods of flooding can drastically reduce the invertebrate fauna of streams (e.g., Jones, 1951; Maitland, 1964; Hoopes, 1974; Siegfried and Knight, 1975). Many components of the benthic fauna can seek refuge in the interstital environment of deep gravel beds during periods of high water (Badcock, 1953; Clifford, 1966; Williams and Hynes, 1974). In streams without deep gravel beds, e.g., Cedar Creek, such refuge is lacking, so many organisms are dislodged by the scouring action of flood waters. The displaced organisms constitute catastrophic drift (Waters, 1965). Streams subject to such seasonal floods generally exhibit a corresponding seasonal change in the density of the benthic fauna (e.g., Gaufin, 1959; Siegfried and Knight, 1975).

In general, California receives more than 80% of its annual rainfall in the five months of November through March, from Pacific storms that move onshore (in 1974-75 most of the rain was concentrated from January-March). Many streams at lower elevations respond rapidly to periods of heavy rainfall. As winter storms move though, washouts occur in these streams as discharge fluctuates with rainfall. The reductions reported here are of about the same magnitude reported for Squirrel Creek, California (Siegfried and Knight, 1975). The fauna of Cedar Creek, like that of many lower-elevation streams, may be adapted to seasonal washouts. The augmentation of water yield in the Cedar Creek watershed may increase the severity of washout, with damage to the benthic community. It will be essential to determine during the next year whether the effects of the seasonal washout are augmented by increased water yields and if harm would result to the benthic communities of the streams in question.

Species diversity was not affected to any great extent by washouts. Diversity values for January collections ranged from 2.64 to 3.21 (Table 2). Despite the drastic reductions in standing crop, diversity increased at Stations 2 and 3 in March, indicating a more balanced community as dominants were decimated. Diversity values at Stations 2 and 3 were generally above 3.00, indicative of balanced benthic communities. Station 1 diversity values were generally nearer to 2.00 than to 3.00, indicating an unbalanced community. Low diversity at Station 1 reflects the poor stream habitat there.

Figure 2. Similarity Coefficients Between Benthic Assemblages Collected at Each Cedar Creek Collection Station, January-May 1975.

	January 1975			March 1975			April 1975			May 1975		
C_s	1	2	3	1	2	3	1	2	3	1	2	3
1												
2	.16			.19			.19			.32		
3	.17	.57		.13	.70		.18	.61		.31	.78	

Figure 3. Similarity Coefficients for Benthic Assemblages Collected at Each Cedar Creek Station on Each Collection Date.

Station 1				
	Jan	Mar	Apr	May
Jan				
Mar	.43			
Apr	.22	.38		
May	.15	.24	.27	

Station 2			
Jan	Mar	Apr	May
.45			
.43	.52		
.28	.39	.52	

Station 3			
Jan	Mar	Apr	May
.44			
.43	.54		
.38	.47	.58	

The results reported provide some base line information for further assessment of the impact of vegetation conversion in the Cedar Creek watershed. Station 1 does not fulfill the requirements of a "control" station with which to compare Stations 2 and 3. A control station is necessary in order to determine whether the reductions in standing crops at Stations 2 and 3 are significantly different from those that would naturally occur. If it is not possible to site a control station on Cedar Creek, Pocock Creek may provide the opportunity for a control station. To determine recovery in the coming year it will be necessary to sample Cedar and Pocock Creeks prior to and immediately after the rainy season and also later in the year.

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Appendix Table A. Hunting Creek Species List - Macrobenthic Invertebrates

- Ephemeroptera
  - Heptageniidae
    - *Heptagenia rubroventris*
  - Siphlonuridae
    - *Siphlonurus spectabilis*
  - Leptophlebiidae
    - *Paraleptophlebia* sp.
    - *Choroterpes* sp.
  - Caenidae
    - *Caenis tardata*
  - Tricorythidae
    - *Tricorythodes fallax*
  - Ephemerellidae
    - *Ephemerella* (*Serrata*) *levis*
  - Baetidae
    - *Baetis* spp.
- Odonata
  - Lestidae
    - *Archilestes californica*
  - Coenagrionidae
    - *Argia* sp.
    - *Hyponeura lugens*
  - Agrionidae
    - *Agrion* sp.
- Plecoptera
  - Nemouridae
    - *Brachyptera* sp.
    - *Nemoura* (*Malenka*) sp.
    - *Capnia maculata*
  - Perlodidae
    - *Isogenes* sp.
    - *Isoperla* sp.
  - Chloroperlidae
    - *Alloperla* sp.
  - Perlidae
    - *Acroneuria californica*
- Hemiptera
  - Corixidae
    - *Graptocorixa californica*
  - Gerridae
    - *Gerris remigis*
- Megaloptera
  - Corydalidae
    - *Neohermes californica*
- Lepidoptera
  - Pyralidae
    - *Parargyractis* sp.
- Coleoptera
  - Dytiscidae
    - *Agabinus* sp.
    - *Abagus* sp.
- Coleoptera (cont.)
  - Hydrophilidae
    - *Berosus* sp.
    - *Tropisternus* sp.
  - Elmidae
    - *Cleptelmis* sp.
  - Psephenidae
    - *Psephenus* sp.
    - *Eubrianx edwardsi*
  - Hydroscaphidae
    - *Hydroscapha natans*
- Trichoptera
  - Hydropsychidae
    - *Hydropsyche* sp.
    - *Cheumatopsyche* sp.
  - Rhyacophilidae
    - *Rhyacophila* (*acropedes* type)
    - *Rhyacophila* (*vocala* type)
  - Glossosomatidae
    - *Agapetus* sp.
  - Hydroptilidae
  - Psychomyiidae
    - *Tinodes* sp.
  - Philopotamidae
    - *Chimarra* sp.
  - Sericostomatidae
    - *Sericostoma griseolum*
  - Brachycentridae
    - *Micrasema* sp.
  - Helicopsychidae
    - *Helicopsyche borealis*
- Diptera
  - Tipulidae
    - *Eriocera* sp.
    - *Hexatoma* sp.
  - Culicidae
    - *Eucorethra underwoodi*
  - Dixidae
    - *Dixa savia*
  - Simuliidae
  - Chironomidae
  - Ceratopogonidae
    - *Palpomyia*
  - Stratiomyidae
    - *Eulalia* sp.
    - *Hermione* sp.
    - *Stratiomys* sp.
    - *Euparyphus* sp.
  - Tabanidae
    - *Chrysops* sp.
  - Dolichopodidae
  - Empididae

Appendix Table B. Eticuera Creek Species List - Macrobenthic Invertebrates

- Ephemeroptera
  - Siphlonuridae
    - *Ameletus* sp.
    - *Siphlonurus spectabilis*
  - Leptophlebiidae
    - *Paraleptophlebia* sp.
  - Ephemerellidae
    - *Ephemerella* (*Serrata*) *levis*
  - Tricorythidae
    - *Tricorythodes fallax*
  - Baetidae
    - *Baetis* sp.
- Odonata
  - Anisoptera
    - *Macromia magnifica*
  - Zygoptera
    - *Agria moesta*
- Plecoptera
  - Nemouridae
    - *Capnia projecta*
    - *Brachyptera* sp.
    - *Isocapnia abreviata*
    - *Nemoura* (*Malenka*) sp.
  - Chloroperlidae
    - *Alloperla* (*Alloperla*) *delicata*
  - Perlodidae
    - *Isogenes* sp.
- Hemiptera
  - Corixidae
    - *Graptocorixa californica*
  - Gerridae
    - *Gerris remigis*
  - Naucoridae
    - *Ambrysus bohartorum*
- Megaloptera
  - Corydalidae
    - *Neohermes californica*
- Coleoptera
  - Dytiscidae
    - *Agabus* sp.
- Trichoptera
  - Hydropsychidae
    - *Hydropsyche* sp.
    - *Cheumatopsyche* sp.
  - Rhyacophilidae
    - *Rhyacophila* (*acropedes* type)
    - *Rhyacophila* (*vocala* type)
- Coleoptera (cont.)
  - Glossosomatidae
    - *Agapetus* sp.
  - Limnephilidae
    - *Limnephilus* sp.
  - Odontoceridae
  - Brachycentridae
    - *Micrasema* sp.
  - Helicopsychidae
    - *Helicopsyche borealis*
  - Psychomyiidae
    - *Tinodes* sp.
  - Philopotamidae
    - *Chimarra* sp.
  - Sericostomidae
    - *Sericostoma griseolum*
  - Hydroptilidae
- Diptera
  - Tipulidae
    - *Hexatoma* sp.
  - Culicidae
    - *Culiseta* sp.
  - Simuliidae
    - *Prosimulium* sp.
  - Chironomidae
  - Ceratopogonidae
    - *Palpomyia*
  - Psychodidae
    - *Pericoma* sp.
  - Tabanidae
    - *Chrysops* sp.

Appendix Table C. Nevada Creek Species List - Macrobenthic Invertebrates

Ephemeroptera
- Siphlonuridae
  - *Siphlonurus spectabilis*
- Ephemerellidae
  - *Ephemerella* (*Serrata*) *levis*
- Baetidae
  - *Baetis* spp.

Plecoptera
- Nemouridae
  - *Capnia* sp.
  - *Brachyptera* sp.
- Perlodidae
  - *Isogenes* sp.

Coleoptera
- Dytiscidae
  - *Agabus* sp.
- Elmidae
  - *Microcylloepus* sp.
- Curculionidae

Trichoptera
- Rhyacophilidae
  - *Rhyacophila* (*acropedes* type)

Diptera
- Tipulidae
  - *Hexatoma* sp.
- Culicidae
  - *Culiseta* sp.
- Chironomidae
- Simuliidae
  - *Prosimulium* sp.
- Ceratopogonidae
  - *Palpomyia* sp.

Appendix Table D. Putah Creek Species List - Macrobenthic Invertebrates

- Ephemeroptera
  - Ephemeridae
    - *Hexagenia* sp.
  - Heptageniidae
    - *Heptagenia* sp.
    - *Rhithrogena morrisoni*
    - *Epeorus* (*Iron*) *albertae*
    - *Epeorus* (*Ironopsis*) *grandis*
  - Siphlonuridae
    - *Ameletus* sp.
    - *Siphlonurus spectabilis*
  - Leptophlebiidae
    - *Paraleptophlebia*
    - *Choroterpes terratoma*
  - Ephemerellidae
    - *Ephemerella* (*Serrata*) *levis*
    - *Ephemerella* (*Serrata*) *cognata*
    - *Ephemerella* (*Walkeri*) *coloradensis*
    - *Ephemerella* (*Needhami*) *maculata*
  - Caenidae
    - *Caenis* sp.
  - Baetidae
    - *Baetis* spp.
    - *Centroptilum* sp.
    - *Paracloeodes abditus*
- Odonata
  - Anisoptera
    - *Ophiogomphus bison*
    - *Progomphus borealis*
  - Zygoptera
    - *Ischnura perparva*
- Plecoptera
  - Pteronarcidae
    - *Pteronarcys princeps*
  - Perlodidae
    - *Isogenes* (*Kogotus*) sp.
    - *Isogenes* (*Osobenus*) *yakimae*
    - *Isoperla* sp.
  - Chloroperlidae
    - *Alloperla* (*Sywallia*) *pallidala*
  - Perlidae
    - *Acroneuria californica*
- Hemiptera
  - Corixidae
    - *Graptocorixa californica*
  - Naucoridae
    - *Ambrysus bohartorum*
  - Gerridae
    - *Gerris remigis*
  - Saldidae
    - *Saldula* sp.
  - Veliidae
    - *Microvelia califoriensis*
- Lepidoptera
  - Pyralidae
    - *Parargyractis* sp.
- Megaloptera
  - Corydalidae
    - *Neohermes californica*
- Coleoptera
  - Psephenidae
    - *Psephenus* sp.
    - *Eubrianx edwardsi*
  - Elmidae
    - *Narpus* sp.
    - *Microcylloepus* sp.
  - Dytiscidae
    - *Oreodytes* sp.
    - *Hydrovates brevipes*
  - Dryopidae
    - *Helichus suturalis*
- Trichoptera
  - Hydropsychidae
    - *Hydropsyche* sp.
    - *Cheumatopsyche* sp.
  - Rhyacophilidae
    - *Rhyacophila* (*acropedes* type)
  - Glossosomatidae
    - *Glossosoma* sp.
  - Odontoceridae
  - Brachycentridae
    - *Brachycentrus americanus*
  - Helicopsychidae
    - *Helicopsyche borealis*
  - Leptoceridae
    - *Oecetis* sp.
  - Hydroptilidae
  - Psychomyiidae
    - *Tinodes* sp.
  - Philopotamidae
    - *Chimarra* sp.
- Diptera
  - Tipulidae
    - *Antocha* sp.
    - *Hexatoma* sp.
  - Chironomidae
  - Ceratopogonidae
    - *Palpomyia* sp.
    - *Alluaydomyia* sp.
  - Stratiomyidae
    - *Eulalia* sp.
  - Simuliidae
  - Culicidae
  - Blepharoceridae
    - *Blepharocera osten-sacteni*
  - Empididae
  - Tabauidae

Appendix

Table E

Total Organisms by Taxon Collected in Surber Square-Foot

Samples from Cedar Creek, January-May 1975

Taxon	14 January 1975			27 March 1975			29 April 1975			30 May 1975		
	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3
Baetis	14	86	197	47	93	90	129	151	151	39	93	68
Paraleptophebia		82	57		11	14	4	43		18	197	93
Tricorythodes		25	32								22	22
E. Ironopsis		262	162		4	4						
E. Iron									11			
Ameletus		14										
Ephemerella		7			11	65		14	65	14	14	7
Argia		7	97		14	4		11	18		32	57
Octogomphus		4	4			4		7	7		7	22
Capnia	93	22			4	4						
Nemoura	22	22	50	4	4	7	11		4	18		
Brachyptera	7			14								
Alloperla		36	29	22	14	4	25	14	7	4	11	11
Isogenus	4		4	4								

Table E (cont.)

Taxon	14 January 1975			27 March 1975			29 April 1975			30 May 1975		
	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3
Acroneuria		136	126		4	14	4	57	53	14	129	65
Saldidae											2	4
undet. Plecop.										11		
Belostoma										4		
Neohermes		4	4							4	4	
Wormaldia	4								7	4		4
Tinodes		11	118					7	4			32
Hydropsyche		671	556		7	14		4	11	7	7	
Cheumatopsycho			4									
R. acropedes	18			4			7					
R. vocala		7	7									
R. vaccua		118	32		4	4		11	29			7
Oxyethira			22			4						
Agraylea		18						4	7	7		18
Neophylax					7							
Ecclisomyia								7	4			
Neothremma			4									

Table E (cont.)

Taxon	14 January 1975			27 March 1975			29 April 1975			30 May 1975		
	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3
Oecetis			11			7		7	4			18
Glossosoma						7						
Lepidostoma		18	7									
Micrasema		438	345		4	14			4			4
undet. Trichoptera		11	4			4						7
Parargyractis			36		4	4		4	4			25
Deronectes	4	7										
Zaitzevia		29	22	4	25				22	4	25	7
Cleptelmis			4									
Ordobrevia					57	39		147	190	4	29	14
Peltodytes			4								4	
Eubrianx		25	68		11	14		7	47		14	39
Hexatoma		14	4		4	4						
Limnophila					4	22		36	53		4	39
Dicranota	4		4									22
Antocha		18	29								32	
Eriocera		11	7			4		7	4		4	

Table E (cont.)

Taxon	14 January 1975			27 March 1975			29 April 1975			30 May 1975		
	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3	Sta 1	Sta 2	Sta 3
Bibiocephala						4	4		4			
Maruina			7						11	4		
Chironomidae	39	1231	2028	32	29	36	18	68	115	316	291	510
Prosimulium			7		7	32			14	4		4
Dixa		4							4	4		
Euparyphus		54			7	54		7	11		11	90
Empididae		7	25									
Ephydridae												29
Bezzia		172	47		7	22		29	4		22	25
Collembola	7											
Turbellaria	4		4									
Oligochaets							11					
Acarina											11	4
Anura											1	25
Gastropoda							4					
Totals*	219	3570	4162	129	334	495	215	642	872	477	983	1270

*Discrepancies in column totals result from round-off of species numbers/m^2.

SECTION V

AN EVALUATION OF THE IMPACT OF CHAPARRAL CONVERSION ON THE VERTEBRATES IN THE CEDAR AND POCOCK CREEK DRAINAGES

W. M. Longhurst
David Gaines
Jeffrey P. Finn

INTRODUCTION AND OBJECTIVES

The proposed conversion of areas of mixed chaparral and cypress vegetation to annual grasslands in the Cedar and Pocock Creek drainages of Napa County will alter the species composition, density, and local distribution of the vertebrates inhabiting the area. The present study considers the impact this conversion will have on amphibians, reptiles, birds, and mammals. Specifically the objectives are the following:

1. Determine from a survey of the literature, the vertebrates to be expected in the area and their respective habitat requirements.

2. Draw special attention to rare, endangered or declining species.

3. Conduct a field survey of the vertebrates present and where possible obtain quantitative data on densities and relative abundance.

4. Predict the impact of the proposed vegetation conversion on the vertebrates.

5. Suggest ways to ameliorate adverse affects.

Because of the limited time available in which to make field surveys, only partial verification of the vertebrates suspected to be in the area was accomplished. Inclement weather hampered field investigations during March to some extent, but with birds in particular it is necessary to carry out observations almost year long because of the transitory movements of many species. Likewise the level of effort necessary to verify the presence of other less common or obscure vertebrates on the area was beyond the scope of this investigation.

None of the vertebrates potentially present in the Cedar and Pocock Creek drainages appears on the list of rare or endangered species (California Fish and Game Commission, 1973). Therefore little would be gained from mounting a

field survey of the intensity and for the time necessary to verify the presence or absence on the study area of all the vertebrate species appearing on the tentative list. Rather it appeared more profitable to examine the potential impacts of the proposed brush conversion on each individual species.

This evaluation was carried out by W. M. Longhurst assisted by David Gaines and Jeffery Finn.

Methods

Information on the distribution and habitat requirements of mammals were obtained from Berry and Berry (1960), Grinnell et al. (1931), Ingles (1965), Longhurst (1940; 1961; 1973). Reptile and amphibian data was taken from Stebbins (1957; 1967), and that on birds from Grinnell and Miller (1944) and McCaskie and DeBenedictus (1963).

From these sources plus the knowledge of the investigators, tentative lists of vertebrates which might be expected to occur on the study area was compiled (Appendices I, II, III). The literature sources and the knowledge of the investigators were also relied upon to estimate the potential impacts of the proposed brush conversion on individual species.

Field investigations extended from February 17 to May 16, 1975. Efforts were directed toward determining what kinds of vertebrates inhabitated the area, their habitat relationships and the densities of certain species. The previously converted plot near Morgan Valley was also studied to assist in estimating the effects of the conversion program.

The study area, the drainages of Cedar and Pocock Creeks and the portion of Hunting Creek into which they drain, was surveyed by car and foot to determine the different plant formations present. Birds were censused within each of the three main plant formations using the following technique developed by Gaines:

1. An arbitrary starting point was chosen within the plant formation.

2. Species and numbers of birds heard or seen were recorded for a period of exactly three minutes; a "squeeking" or "peeshing" sound was used during the last two minutes to attract silent or furtive species.

3. The procedure was repeated at additional stops spaced approximately 100 meters apart along as straight a path as possible.

4. Individual birds known or strongly suspected to have been counted on a previous stop were not recounted.

Data so gathered are summarized in Tables 2-6 using the following statistics:

t. -- total birds recorded

avg. -- average number of birds recorded per stop

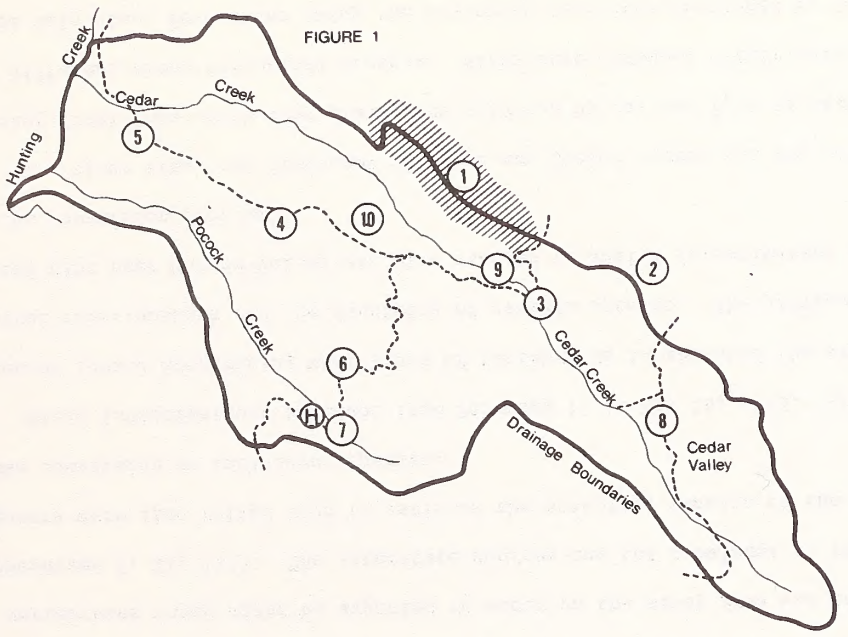
freq. -- frequency, i.e., the fraction of the total number of stops on which the species was recorded.

Birds heard or seen while walking between stops, but unrecorded on the census proper, were recorded with a "plus" (+). Censuses were undertaken in chaparral at sites 1, 4, and 6, in oak woodland at sites 5 and 7 and in cypress woodland at site 2 (refer to Figure 1). All censuses were conducted between 1/2 and 4-1/4 hours after dawn.

More detailed data on breeding bird densities and habitat was obtained for site 1 (Figure 1). The mapping methods recommended by the International Bird Census Committee (Svensson, 1970) were used to determine the numbers of territorial pairs.

Efforts to detect nocturnal birds (such as owls) through playing tape recordings of their calls were made on the evenings of April 25, May 14, and May 15.

To assist in predicting the probable nesting avifauna in areas converted to annual grassland, a grassland site east of the Knoxville Road 3.5 miles north



Field survey sites on the study area

(See key page 5)

Figure 1. Key to Sites.

1. Breeding bird census plot and small mammal trapping locality.
2. Bird census -- Sargent cypress woodland.
3. Bird census — chaparral and riparian thickets along creek. Cedar Creek campground.
4. Bird census -- chaparral interspersed with natural grassy glades. Deer pellet plot count -- natural grassy glade. Ridge between Cedar and Pocock Creeks.
5. Bird census -- Oak woodland with grass understory near junction of Cedar and Hunting Creeks.
6. Bird census -- Broken chaparral; recovering from recent burn. Pocock Creek Heliport.
7. Bird census -- Oak woodland and broken, nonserpentine chaparral. Pocock Creek Campground.
8. Bird census -- grassland, chaparral and Cypress Forest edge. Cedar Valley.
9. Small mammal trapping — chaparral. Transect crossed Cedar Creek drainage from ridge to ridge.
10. Deer Pellet Plot Count -- Serpentine chaparral. Ridge between Cedar and Pocock Creeks.

H. Pocock Creek Heliport.

of Knoxville was censused. The census was conducted on the 15 May at the height of the breeding season. At this time birds with eggs or young can usually be recognized by their behavior when flushed from the vicinity of their nests.

Vernacular and scientific names for reptiles and amphibians follow Stebbins (1966); those for birds the American Ornithologist's Union Check-list (1957), and the 32nd Supplement (1973); scientific names are given in Appendix 1. Botanical nomenclature follows Munz (1959).

Mammal investigations included a general reconaissance of the two drainages, making pellet counts to determine deer densities, trapping small rodents, collecting and identifying scats, and surveying the area for any other signs which would indicate the presence of various species. In this regard such evidence as tracks, burrows, runways, trails, and feeding activity were used.

Results

I. Birds, Reptiles, and Amphibia

a. Vegetation and habitats

The study area was divided into the following three vegetation formations (refer to Figure 1 for site locations):

1. Cypress woodland (cyp). Sargent Cypress (Cupressus sargentii) dominant, but interspersed with Leather Oak (Quercus durata) Whiteleaf Manzanita (Arctostaphylos viscida), Jepson Ceanothus (Ceanothus jepsonii) and Digger Pine (Pinus sabiniana). Herbaceous vegetation sparse. Canopy height 3-10 meters. Canopy cover about 60 percent. Woody vegetation evenly dispersed. Site 2. Interrupted by moist grassland (meadow) in Cedar Valley (site 8). Plant species composition indicative of serpentine substrate.

2. Chaparral (chap). Variable within study area in terms of species composition, height, and cover. Dominant species, depending on the locale, are Whiteleaf Manzanita, Leather Oak, and Chamise (Adenostoma fasciculatum). Other widespread shrubs are Jepson Ceanothus, Buckbrush (C. cuneatus), Congdon Silktassel (Garrya congdonii), Chaparral Flowering Ash (Fraxinus dipetala), Toyon (Heteromeles arbutifolia), and Macnab Cypress (C. macnabiana). Plant species composition is indicative of serpentine substrate. A quantitative description of the chaparral vegetation on the breeding bird census plot (Site 1) is given in Appendix IV. At site 4, Whiteleaf Manzanita dominates a dense shrub cover interspersed with "islands" of grassland, thus providing "edge" type habitat. Chaparral in the vicinity of the Pocock Heliport (site 6) is recovering from a recent burn. Many of the shrubs, in particular, Chamise, have stump-sprouted, but there is still considerable herbaceous growth in the intervening open spaces. Elsewhere herbs are present in considerable variety along road cuts in naturally occurring open places.
3. Oak woodland (oak). Blue Oak (Q. douglasii) dominant, but interspersed with Digger Pine, Toyon (H. arbutifolia) and Common Manzanita (A. manzanita). Herbaceous vegetation (mainly Mediterranean annuals) forms a well-developed understory during the rainy season. Canopy height 6-15 meters. Trees scattered. Canopy cover about 10 percent. Herbaceous cover about 70 percent in spring. Sites 5 and 7.

Mesic micro and aquatic habitats along Cedar and Pocock Creeks are of particular importance to amphibians (sites 3 and 7). Neither watershed supports the phreatophytic woody vegetation (tree willows, cottonwoods, alders, etc.) that characterize larger streams. However the dense thickets of California Bay (Umbellularia californica), Willow (Salix breweri), Coffeeberry (Rhamnus californica), Sargent Cypress, Squawbush (Rhus trilobata) Western Azalea (Rhododendron occidentale) and Sweet-scented Shrub (Calycanthus occidentalis) do form a distinctively riparian habitat. Presence of Azalea is indicative of serpentine soil in the inner coast ranges.

b. Influence of weather conditions on the field study

The 1974-75 season was characterized by below average precipitation during the fall and early winter and above average precipitation and cold temperatures during March and April (based on conditions prevailing in northern California generally during the period). This delayed nesting of resident birds and the arrival of summer visitors and migrants. Reptiles were not in evidence until May.

c. Amphibians and reptiles

The reptiles and amphibians of the Cedar and Pocock Creek drainages are enumerated in Table 1. In contrast to birds, many amphibians and reptiles are secretive and hard to locate. Failure to find a species does not imply it does occur, or even that it is uncommon. All species except those listed as possible in Table 1 are very probably denizens of the area.

TABLE 1. Amphibians and reptiles found in the Cedar and Pocock Creek drainages.

Species	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat in area
SALAMANDERS						
Newt (Taricha ?; see text)	-	+	+	+	+	grassland, woodland; breeds in ponds, slow streams
Ensatina	-	-	-	-	-	oak, chap
California Slender Salamander	-	+	-	-	-	oak
Arboreal Salamander	-	-	-	-	-	oak
FROGS AND TOADS						
Western Toad	-	-	-	-	+	throughout; breeds in ponds and slow streams
Pacific Tree Frog	+	+	+	+	+	plant growth near water; breeds in ponds, slow streams
Foothill Yellow-legged Frog	+	+	+	+	+	streams and rivers with rocks and sunny banks; closely restricted to water
(Red-legged Frog)						possible along Hunting Creek
(Bullfrog)						permanent water; possible along Hunting Creek
TURTLE						
Western Pond Turtle	-	-	+	-	-	permanent ponds and streams grown to such aquatic vegetation as watercress, water lilies, tules, etc.
LIZARDS						
Western Fence Lizard	-	-	-	+	+	oak, chap, grassland where rocks, dead wood, fences, etc. present for shelter and basking
Sagebrush Lizard	-	-	-	+	+	chap, cyp
Coast Horned Lizard	-	-	-	-	-	oak, chap; seems to prefer dry stream beds
Western Skink	-	-	-	+	-	oak, riparian; most common near streams
Western Whiptail	-	-	-	-	+	chap
Southern Alligator Lizard	-	-	-	+	+	oak, riparian, chap; most common in moist microhabitats

TABLE 1 - continued

Species	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat in area
SNAKES						
Ringneck Snake	-	-	-	-	-	oak, moist microhabitats
Sharp-tailed Snake	-	-	-	-	-	oak; moist microhabitats; apparently feeds entirely on slugs
Racer	-	-	-	-	+	grassland; often near water
Coachwhip	-	-	-	-	-	throughout
Striped Racer	-	-	-	-	+	chap
Gopher Snake	-	-	-	-	-	throughout
Common Kingsnake	-	-	-	-	+	throughout
Long-nosed Snake	-	-	-	-	-	probably broken chaparral; rare and poorly known in this area
Common Garter Snake	-	-	-	-	-	oak, grassland; tends to remain near water
Western Terrestrial Garter Snake	-	-	-	-	+	throughout
Western Aquatic Garter Snake						probably occurs along Hunting Creek
Night Snake	-	-	-	-	-	throughout
Western Rattlesnake	-	-	-	-	+	throughout

The following comments supplement the information in Table 1:

Newt. Newts were observed along Cedar and Pocock Creeks on all field trips except 10 February. They became increasingly numerous as the season advanced, with a maximum of 38 individuals (29 males and 9 females) counted in a single, deep pool along Pocock Creek on 14 May. Specific identity was puzzling, since the newts possessed characters of both the California and rough-skinned species. The lower eyelid was invariably dark-colored in all individuals examined, suggesting Taricha granulosa. The few eggs discovered were laid singly, further indicating this species. But other characters suggested T. torosa, e.g., the eyes reached the outline of the head as viewed from above. Both are possible -- and the Putah Creek watershed is reputed to be a zone of hybridization.

Ensatina. Although none was found, this species has been found in similar oak woodland and chaparral habitats in the Vaca-Berryessa Mountains of Solano and Yolo Counties.

California Slender Salamander. Under decomposing wood in oak woodland near Pocock Campground on 28 February; seemingly less common than in similar habitats in other parts of the north coast ranges.

Arboreal Salamander. This species is fairly common in oak woodland habitat in the Vaca Mountains, hence it may also occur in the study area.

Western Toad. Several active in early evening, 14-15 May. Probably fairly common.

Pacific Tree Frog. Choruses heard in Cedar Valley and along Cedar, Pocock, and Hunting Creeks. Most vocal in April. Probably commonest annuran.

Foothill Yellow-legged Frog. Fairly common along Cedar and Pocock Creeks. Tadpoles observed 15 May.

Red-legged Frog and Bullfrog. Red-legged frogs were found along Cache Creek in habitat similar to that along Hunting Creek. Populations throughout California are declining due to competition with the introduced Bullfrog.

Western Pond Turtle. This species occurs along Eticuera Creek near Knoxville, hence it should occur along Hunting Creek as Well.

Western Fence Lizard. Mainly along Cedar and Pocock Creek and in oak woodland.

Sagebrush Lizard. Only Sceloporus observed in cypress woodland. Outnumbers Fence Lizard in serpentine chaparral. Strictly ground dwelling.

Coast Horned Lizard. Probably uncommon.

Western Whiptail. In serpentine chaparral 14-16 May.

Southern Alligator Lizard. Observed along Cedar and Pocock Creeks.

Ringneck Snake. One found 3 May on plot near Morgan Valley.

Gopher Snake. None was observed although probably fairly common.

Long-nosed Snake. Status in north coast ranges conjectural and in need of study; none was observed.

Night Snake. Status conjectural; possibly fairly common.

BIRDS

The birds detected in the Cedar and Pocock Creek drainages are enumerated in Table 2 (resident species), table 3 (wintering species), table 4 (summering species), and table 5 (migrants and transients). Table 6 lists additional species of probable or possible occurrence that were not actually detected. The bird census techniques were relatively thorough; hence it may be concluded that the species in Table 6 are uncommon or sporadic.

In summary, 93 species of bird probably occur in the area. Of these 73, or 78 percent, were detected during the present study. Of these 48 percent were resident, 17 percent were wintering only, 24 percent were summering only and the remaining 11 percent were migrants or transients.

The comments which follow the tables supplement the tabularized data. An asterisk (*) by a bird's name indicates it is discussed in the text.

Three minute census data are computed for the habitat where the bird most frequently occurs. Data from days on which the species was not recorded are not considered. Figures are given only for those birds whose average numbers per census were .15 or over. All figures are rounded to the nearest five percent.

TABLE 2. Resident birds.

Species	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat	Three minute census data # censuses	avg.	freq.
Red-tailed Hawk*	+	+	+	+	+	oak, grass			
Golden Eagle*	-	-	+	+	+	oak, grass			
Kestrel	+	-	-	+	+	oak			
Mountain Quail*	-	+	+	+	+	chap, cyp	34	.35	.30
California Quail*	+	+	+	+	+	oak			
Greater Roadrunner*	-	-	-	-	+	chap			
Screech Owl*	-	-	-	-	+	cyp, oak			
Great Horned Owl	-	-	-	-	+	oak, cyp			
Ann'a Hummingbird*	+	+	+	+	+	chap, oak, cyp	41	.15	.15
Common Flicker*	+	+	+	+	+	oak, chap			
Acorn Woodpecker	+	+	-	-	+	oak			
Nuttall's Woodpecker*	+	+	+	+	-	oak			
Black Phoebe*	+	+	-	-	-	riparian			
Scrub Jay	+	+	+	+	+	oak, chap, cyp	13	.75	.45
Raven*	-	-	-	-	-				
Plain Titmouse	+	+	+	+	+	oak, cyp, chap			
Bushtit	-	+	+	+	+	oak, chap			
White-breasted Nuthatch	+	-	-	-	-	oak			
Wrentit*	+	+	+	+	+	chap	41	1.00	.70
Bewick's Wren	+	+	+	+	+	chap, oak, cyp	41	.35	.35
Rock Wren*	-	-	-	-	+	rocks			
California Thrasher*	+	+	+	+	+	chap	41	.40	.35
Western Bluebird*	+	+	+	-	+	oak			
Starling*	-	-	-	-	+	oak			

*Discussed in text

Table 2 - continued

Species	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat	Three minute census data # censuses	avg.	freq.
Hutton's Vireo*	+	+	+	+	+	cyp, oak			
Western Meadowlark*	+	-	-	-	-	grassland			
House Finch*	-	+	+	-	+	oak, chap			
Lesser Goldfinch*	-	+	+	+	+	chap, oak	34	.20	.20
Rufous-sided Towhee*	+	+	+	+	+	chap	41	.60	.45
Brown Towhee*	+	+	+	+	+	oak, chap			
Lark Sparrow*	-	+	+	+	+	oak			
Rufous-crowned Sparrow*	-	+	-	-	+	chap			
Sage Sparrow*	-	+	+	+	+	chap	34	.40	.30
Song Sparrow*	+	-	-	-	-	riparian			

Total: 33

*Discussed in text.

Red-tailed Hawk. In area, requirements seem to be tall, stout trees, such as blue oak and digger pine, in which to roost and nest and open terrain in which to forage, as, for instance, at Cedar Valley and along lower reaches of Cedar and Pocock Creeks. At least two pairs were nesting in area during the study.

Golden Eagle. Requirements similar to red-tailed, but territories much larger. Observations were as follows: lone adults on 10 and 26 April and a lone immature on 14 May. Four of indeterminant age observed over Pocock Creek on 3 May. Probably within foraging beat of pair nesting in vicinity.

Mountain Quail. Frequently heard, infrequently seen except from vehicle along roads through dense chaparral. One flushed as dusk from a Sargent Cypress near Cedar Valley on 14 May, suggesting use of cypress as roosting place. Keeps to continuous, dense chaparral cover.

California Quail. Occurs in oak woodland and chaparral-grassland edge, as in areas 4, 5, and 7. Will forage in open grassland but depends upon chaparral for escape cover. At least scattered shrubs required for refuge and nesting, dense foliaged trees for night roosting and a source of water during the dry season.

Greater Roadrunner. Prefers mixture of open ground and tracts of chaparral. Precise habitat requirements in north coast ranges poorly understood. Three heard calling simultaneously along Cedar Creek 15 May.

Screech Owl. Common in cypress woodland and oak. At least five birds were heard along one-half mile of road north of Cedar Valley 14 May.

Anna's Hummingbird. Males were most common in chaparral along ridges; displaying was observed on all field trips except those during May. Nesting females appeared to be utilizing the denser growth along streams, as along

Cedar and Pocock Creeks and at the lower end of Cedar Valley. Most nectar-feeding seemed to be on Chaparral Flowering Current (Ribes malvaceum) and Indian Warrior (Pedicularis densiflora) during February and on Paintbrush (Castilleja spp.) during April and May.

Common Flicker. Most common along Cedar and Pocock Creeks, where there were several nesting pairs.

Black Phoebe. Individuals observed along Hunting and Cedar Creeks. Probably nests along Hunting Creek.

Raven. Observed over Pocock Creek, 3 May.

Wrentit. Common wherever there is dense cover.

Rock Wren. Pair near Pocock Heliport 15 May. Probable elsewhere in vicinity of rock outcroppings.

California Thrasher. Restricted to continuous, dense chaparral cover.

Western Bluebird. Requires well-spaced trees with openings of grassland, and woodpecker holes for use as nesting cavities.

Starling. Pair flying over oak woodland 14 May. Probably nests in Paradise Valley. Introduced in North America. May compete with native hole-nesting birds for nest sites.

Hutton's Vireo. In this area they seemed partial to vicinity of streams, as along Cedar and Pocock Creeks and in Sargent Cypress woodland. Observed constructing nest in Sargent Cypress 28 February.

Western Meadowlark. Lone individual in Cedar Valley 17 February. A few probably occur along Hunting Creek.

House Finch. Partial to open terrain with scattered trees and bushes.

Lesser Goldfinch. Habitat preference similar to that of House Finch, but more tolerant of chaparral. Nest with two eggs discovered in oak woodland 15 May.

Towhees. Rufous-sided more prevalent in dense, continuous chaparral; brown towhees in edge situations and oak woodland and appear to winter in continuous chaparral, but not to breed there.

Lark Sparrow. Prefers open terrain with scattered trees and shrubs; common in Cedar and Paradise Valleys; possibly absent in winter.

Rufous-crowned Sparrow. Pair near Pocock Heliport 29 February. Possibly same pair apparently nesting above Pocock Campground 16 May. Habitat open chaparral with intervening patches of herbaceous vegetation. Northernmost known station in coast ranges is near Mt. St. Helena, Sonoma County.

Sage Sparrow. Restricted to continuous, dense chaparral.

Song Sparrow. Observed only along Hunting Creek, where it probably nests.

TABLE 3. Wintering birds, i.e., birds that winter in the area, but nest elsewhere.

Species	Probable dates present	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat	Three minute census data # censuses	avg.	freq.
Sharp-shinned Hawk*	Oct-March	+	-	-	-	-	chap, oak			
Yellow-bellied Sapsucker	Oct-March	+	+	-	-	-	oak, cyp			
American Robin*	Oct-April	+	+	-	-	-	oak, chap			
Varied Thrush*	Nov-March	-	+	-	-	-	oak, chap			
Hermit Thrush*	Oct-April	+	+	+	+	-	chap, oak			
Ruby-crowned Kinglet	Oct-April	+	+	-	-	-	chap, cyp oak	25	.30	.30
Cedar Waxwing*	Sept-May	-	+	-	-	-	oak, cyp			
Yellow-rumped Warbler	Oct-April	+	+	-	-	+	oak, cyp, chap			
Purple Finch*	Oct-April	-	-	+	-	-	oak			
Dark-eyed Junco*	Oct-April	+	+	+	-	-	oak, cyp	9	3.3	.10
Golden-crowned Sparrow*	Sept-May	+	+	+	-	-	chap	31	.50	.10
Fox Sparrow	Sept-April	+	+	+	+	-	chap, oak	35	.25	.25

Total: 12

*Discussed in the text.

Sharp-shinned Hawk. Could conceivably breed in area, is known to nest in open deciduous or coniferous woodland south to Alameda and Monterey Counties. Probably fairly common during winter season.

American Robin. Numbers of wintering birds fluctuate from year to year depending on weather conditions and availability of such foods as Toyon, Manzanita and Mistletoe berries. Probably nests along Hunting Creek.

Varied Thrush. Numbers fluctuate from year to year; like Robin feeds heavily on fruits of Toyon and Manzanita, as well as fallen acorns.

Hermit Thrush. More prone than the other thrushes to inhabit continuous chaparral; also depends on winter berries of Toyon, Manzanita, etc.

Cedar Waxwing. Like Robin and Varied Thrush, numbers fluctuate from year to year and even from week to week; in addition to Manzanita and Toyon, fond of Mistletoe berries.

Purple Finch. Numbers fluctuate from year to year.

TABLE 4. Summer residents, i.e., birds that nest in the area, but winter elsewhere.

Species	Probable dates present	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat	Three minute census data # censuses	avg.	freq.
Turkey Vulture	March-Oct	-	-	+	+	+	oak			
Mourning Dove	April-Oct	-	-	+	+	+	chap, oak	16	.25	.25
Poor-will*	May-Sept	-	-	-	-	+	chap, cyp			
Western Kingbird*	April-Aug	-	-	-	+	+	oak			
Ash-throated Flycatcher*	May-Aug	-	-	-	-	+	oak, chap, cyp			
Western Wood Peewee*	May-Aug	-	-	-	-	+	oak, riparian			
Violet-green Swallow*	April-Sept	-	-	-	+	+	oak, aerial			
Blue-gray Gnatcatcher*	April-July	-	-	-	+	+	chap	10	.60	.40
Solitary Vireo*	April-Aug	-	-	-	-	+	cyp			
Orange-crowned Warbler	April-Aug	-	-	+	+	+	chap, oak	16	.30	.25
Black-throated Gray Warler*	May-Aug		-	-	-	+	cyp, ?			
Wilson's Warbler*	April-Aug	-	-	-	-	+	riparian			
Northern Oriole*	April-Aug	-	-	-	+	+	oak			
Brewer's Blackbird	April-Aug	-	-	-	+	+	oak			
Brown-headed Cowbird*	April-July	-	-	-	+	+	chap, oak	10	.30	.20
Black-headed Grosbeak	April-July	-	-	-	+	+	oak			
Lazuli Bunting*	April-July	-	-	-	-	+	chap, riparian			
Lawrence's Goldfinch*	April-Aug	-	-	-	-	+	cyp			
Chipping Sparrow*	April-Aug	-	-	-	-	+	oak			

Total: 19

*Discussed in the text.

Poor-will. Common. Can be heard calling from shrub-covered slopes at dusk from almost anywhere within area; five birds heard simultaneously from Cedar Valley 14 May.

Western Kingbird. Prefers dry open areas where one or two trees, living or dead, provide outlook posts and roosting and nesting sites.

Ash-throated Flycatcher. Prefers chaparral but requires tree-holes or cavities for nesting; these may be work of woodpeckers or the result of natural splitting or decay.

Western Wood Peewee. Constructing nest in Digger Pine along Cedar Creek 16 May.

Violet-green Swallow. Observed to utilize woodpecker-excavated cavities in blue oaks for nesting sites.

Blue-gray Gnatcatcher. Nest discovered in chaparral 14 May contained a cowbird egg on 16 May.

Solitary Vireo. Singing bird apparently on territory near Cedar Valley 15 May.

Black-throated Gray Warbler. Nesting probable, but needs confirmation.

Wilson's Warbler. Nesting along Cedar Creek.

Northern Oriole. Nesting near Pocock Campground and in Cedar Valley.

Brown-headed Cowbird. Unknown in northern California before the 1920's spread into remoter areas, such as that of the present study, probably recent. Egg-parasitic, i.e., deposits its eggs in the nests of other species, which raise the cowbird young at the expense of their own offspring. Probable high frequency hosts in the study area are Hutton's Vireo, Orange-crowned Warbler and Blue-gray Gnatcatcher. A nest of the latter species contained an egg of the cowbird on 16 May.

Lazuli Bunting. In broken chaparral in vicinity of water, as near Pocock Creek.

Lawrence's Goldfinch. Apparently restricted to cyprews woodland, where two pairs were observed 15 May. This is near the northern limit of the known range of this species.

Chipping Sparrow. Nesting in vicinity of Pocock Creek.

TABLE 5. Migrants and transients.

Species	17 Feb	28 Feb	10 Ap	25-26 Ap	14-16 May	Habitat	Status
Band-tailed Pigeon*	-	-	-	-	+	oak	probably transient; see text
Rufous Hummingbird	-	-	+	+	-	chap, oak	migrant
Western Flycatcher*	-	-	-	-	+	oak, riparian	migrant?
Cliff Swallow*	-	-	-	-	+	aerial	transient
Townsend's Warbler	-	-	-	-	+	cyp	migrant
Hermit Warbler	-	-	-	-	+	cyp	migrant
MacGillivray's Warbler*	-	-	-	-	+	chap	migrant?
Western Tanager	-	-	-	-	+	oak	migrant

Total: 8

*Discussed in the text.

Band-tailed Pigeon. Two were observed near Cedar Creek on 14 May. Probably nests some years. Feeds primarily on acorns; if acorn crop fails, wandering flocks seek fruits of Toyon, Manzanita, Coffeeberry, etc.

Western Flycatcher. A few might nest along creeks.

Cliff Swallow. Probably nests in vicinity.

MacGillivray's Warbler. Might nest in area.

TABLE 6. Species unrecorded on field surveys but of probable or possible occurrence in area.

Species	Probable status
Great Blue Heron	occasional along Hunting Creek
Cooper's Hawk	migrant and winter visitor; should be fairly numerous
Prairie Falcon	transient or resident; probably forages over area; more common winter; declining in California and considered a "rare" species by CFG
Merlin	migrant and winter resident; rare but probably regular in area
Pygmy Owl	transient or resident; not unlikely as breeding bird in cypress or oak woodland
White-throated Swift	transient; probably occasional overhead
Allen's Hummingbird	probably common fall and rare spring migrant
Calliope Hummingbird	migrant, probably uncommon
Belted Kingfisher	occasional along Hunting Creek; could nest
Pileated Woodpecker	probably occasional transient; known from Eticuera Creek to the east and Mt. St. Helena, Cobb Mountain, etc. to west
Lewis' Woodpecker	Probably common some winters and occasional breeds; notably erratic in its occurrence in any one area from year to year. Many seen along Eticuera Cr., May 3.
Hairy Woodpecker	transient or winter visitor
Downy Woodpecker	possible along Hunting Creek
Say's Phoebe	probable in winter
Willow Flycatcher	possible migrant; could nest along Hunting Creek
Hammond's Flycatcher	
Dusky Flycatcher	migrant; probably uncommon
Olive-sided Flycatcher	possible migrant
Tree Swallow	migrant; might breed along Hunting Creek
Rough-winged Swallow	migrant; might breed in area
Barn Swallow	migrant; might breed in Paradise Valley
Purple Martin	migrant; might breed
Canyon Wren	along Hunting Creek; possible elsewhere
Swainson's Thrush	migrant; could nest along Hunting Creek

Table 6 - continued

Species	Probable status
Townsend's Solitaire	probably uncommon winter visitor
Golden-crowned Kinglet	sporadic; probably present some winters, absent others
Phainopepla	possible resident
Warbling Vireo	migrant; could nest along Hunting Creek
Nashville Warbler	migrant
Yellow Warbler	migrant; could nest along Hunting Creek
Pine Siskin	sporadic; probably common some winters
American Goldfinch	probably occurs in wintering flocks of finches
White-crowned Sparrow	probably winters in parts of Paradise Valley
Lincoln Sparrow	possible migrant and visitor along Hunting Creek and elsewhere

Results of the breeding bird census follow in Table 7. The size of the census plot was 13.7 hectare (33.85 acres) derived from the length of the fire road along the ridge and a strip 50 meters wide on each side. Birds beyond this 50 meter strip were not censused. Poor-wills were censused by call on the evening of May 15.

TABLE 7. Results of breeding bird census in serpentine chaparral north of Cedar Creek, Napa County.

Species	Territorial Males	Territorial males/km^2
Wrentit	5	36
Rufous-sided Towhee	5	36
Sage Sparrow	5	36
Bewick's Wren	4	29
California Thrasher	3	22
Poor-will	3	22
Lesser Goldfinch	3	22
Anna's Hummingbird	3	22
Blue-gray Gnatcatcher	2	
Orange-crowned Warbler	2	
Mountain Quail	2	
Bushtit	1	
TOTALS: 12 species	38	277

The grassland census revealed but two species -- Western Meadowlark and Horned Lark -- utilizing the grassland habitat for nesting. Kestrel, Western Kingbird, House Finch, Brown Towhee, Lesser Goldfinch, and Lark Sparrow were observed to forage in the grassland, but retreated to the surrounding woody vegetation (oak woodland and chaparral) for shelter and nesting.

DISCUSSION -- Birds, Reptiles, and Amphibia

1. The aquatic environment

Newt, Western Toad, Pacific Tree Frog, and Foothill Yellow-legged Frog are known to deposit eggs and pass their larval stage in Cedar and Pocock Creeks. These species require some standing water into midsummer to complete their life cycles. The presence of small fish (probably Cyprinidae) in Cedar and Pocock Creeks implies that water remains in these creeks throughout the year. Vegetation conversion would cause a more reduced runoff from the watershed during periods of precipitation, and would also increase the amount of water that would penetrate the soil and be dissipated slowly through subsurface flow. Dry season evapotranspiration will also be reduced through chaparral removal. Maintenance of water in Cedar and Pocock Creeks during the late summer is dependent on this subsurface flow and if the flow in these creeks during the summer is augmented, populations of Newt, Western Toad, and Pacific Tree Frog will increase. The Yellow-legged Frog will also probably be benefitted.

Another possible consequence of vegetation conversion will be an increased initial inflow of sediment and organic matter into the creeks. Information is lacking on the specific effects of these materials on the eggs of amphibians. However, Newt and Yellow-legged Frog, in particular, usually deposit their eggs in water with low turbidity. This is not always true of the other two species.

Inflow of organic matter could also increase algal growth and deplete the dissolved oxygen level in the aquatic environment. This could affect the larvae of the Yellow-legged Frog, which are almost always found in flowing, well oxygenated streams. The other species probably tolerate more eutrophic conditions during their larval stages, since they often complete their development in pools of standing water left after streams cease to flow.

2. The terrestrial environment

a. Changes in habitat

The areas proposed for conversion from woody vegetation to annual grassland are not contiguous, but rather form a patchwork pattern of separate units. These areas consist primarily of chaparral vegetation similar to that on the breeding bird census plot. Essentially the conversion will reduce chaparral habitat and increase annual grassland habitat, thereby increasing grassland and chaparral edge as well.

Slopes exceeding 35 degrees will not be converted. In effect this locates the converted areas along the ridges above the creeks, since both Cedar and Pocock Creeks flow through steep, V-shaped canyons. Therefore the annual grassland habitat created by conversion will be relatively distant from permanent water.

It has been theorized, and to some extent verified in fact, that the ecotone between two habitat types may be richer in numbers and kinds of organisms than either habitat individually; this has been called "edge effect." To enhance this effect, the conversion areas should be irregularly shaped with clumps of trees and brush left standing within the clearings. It has been suggested that the net result will be increased numbers of wildlife. This cannot be accepted a priori, since most of the data is from forest edge, not from shrub edge (Odum, 1971, pp. 157-158). Furthermore at least one recent breeding bird census from California arrived at the opposite conclusion, i.e., that breeding bird density and diversity was lower in edge than it was within the habitat (DeSante, 1972). Edge may be of most importance for feeding birds. Finally the existing chaparral cover is not continuous, but rather is interspersed with many small openings. This is characteristic of chaparral already growing on a serpentine substrate. On the breeding bird census plot, for instance, percent cover

70 percent (based on sample transects). Thus a significant, perhaps adequate amount of edge already exists within the chaparral habitat. The type of edge created by the conversion would be especially valuable to those species which feed in grassland and retreat to chaparral for cover. Even though serpentine chaparral is not typically a dense stand, still the seed producing grasses and forbs are scarce to nonexistent between the bushes.

b. Short-term Impact

Clearing of chaparral with tractors and anchor chains will very likely initially reduce reptile and certain bird populations significantly. Many reptiles will be killed outright. Displaced birds will be forced into adjacent areas of suitable habitat already occupied by other individuals of the same species. Many, if not most, will ultimately perish.

Applications of herbicides will be required in the second and fourth years after conversion to prevent reestablishment of shrubs (1/2 gallon 2, 4-D, 1/2 gallon 2, 4, 5 TP Silvex, 1/2 gallon diesel fuel mixed with 18-1/2 gallons water/acre is recommended). Lack of information prevents reliable prediction of impact of spraying on reptiles and birds inhabiting the clearing. Timing of the sprayings (spring) coincides with the height of bird nesting -- hence might have an impact on nesting success.

c. Long-term Impact on Terrestrial Amphibians and Reptiles

The Western Toad is the only amphibian found in the study area which ranges regularly into chaparral habitat. Other terrestrial amphibians occur primarily in oak woodland. No specific affects are forecast for any of these species during the terrestrial parts of their life cycles.

The paucity of information in the literature and the limited field data make it difficult to predict how conversion will affect the reptilian fauna. The groupings which follow are therefore somewhat speculative:

Group 1. Reptiles which rarely occur in chaparral or open grassland, or, if they do range into these habitats, may occur primarily in the vicinity of water.

1. Southern Alligator Lizard
2. Ringneck Snake
3. Sharp-tailed Snake
4. Common Garter Snake
5. Western Terrestrial Garter Snake

These species will probably be unaffected by the vegetation conversion.

Group 2. Reptiles which occur primarily in chaparral and rarely venture more than a few meters from woody cover.

1. Sagebrush Lizard
2. Coast Horned Lizard
3. Western Whiptail
4. Striped Racer

Such species forage primarily on the ground, but are dependent on shrubs to hide them from predators (such as hawks), to provide leaf litter in which to forage for insects and other small animals and for shade in which to cool their body temperatures during hot days. As existing chaparral meets these requirements optimally, their aggregate populations are likely to decline as a result of the vegetation conversion. This can be ameliorated by leaving clumps of woody vegetation within the clearings.

Group 3. Reptiles which frequently range into open grassland of any type.

1. Racer
2. Coachwhip
3. Gopher Snake

These snakes hunt lizards and small mammals, primarily in open country. Rodent burrows are frequently entered -- both in search of prey and to escape unfavorable surface weather conditions. Their aggregate numbers will probably increase as a result of the vegetation conversion.

Group 4. Reptiles which frequently occur in open grassland given the presence of large rocks, stumps, boards, etc.

1. Western Fence Lizard
2. Common Kingsnake
3. Night Snake
4. Western Rattlesnake
5. Western Skink

Rocks, tree trunks, stumps, etc., like shrubs, provide shelter from predators and foraging space. Additionally they provide exposed surfaces on which to bask -- an important thermoregulatory behavior. The above reptiles are likely to adapt to the grassland clearings providing the backing site requirement is met.

In summary, of the 17 reptiles considered, 29 percent will probably be unaffected by the vegetation conversion, 24 percent will decrease in numbers, 18 percent will increase in numbers and the remaining 29 percent will remain at present population levels or increase in numbers providing there are large rocks, stumps, tree trunks, etc., present in the clearnings. No species is likely to disappear entirely.

d. Long-term Impact on Birds

The number of birds utilizing various habitat types has been summarized by Wiens (1973). He found that grasslands average 4 species and 230 individuals per km^2 and that shrub-type habitats average 12 species and 1150 individuals per

km^2. Much of his data, however, derives from parts of North America not having a Mediterranean climate similar to California. In California chaparral and grassland there is only a relatively short period in spring when water and temperature curves coincide favorably for maximum primary production -- approximately mid-March until mid-May. Therefore it is possible to predict the California habitats will support fewer birds than similar habitats in areas of summer precipitation.

Data on numbers of birds nesting in various California habitats has been assembled by Gaines (1974). In chaparral 12 censuses averaged to 12.2 species (SD - 2.7) and 485 territorial males per km^2 (SD - 107), i.e., to compare with Wiens (1973) data, 970 individuals per km^2. There seems to be no significant difference between Wiens estimate for shrub-type habitat and data from breeding bird censuses in California chaparral. (Note: to obtain bird densities/acre divide densities/km^2 by 247.)

Unfortunately there are no comparable data from California annual grassland analagous to that planned for the Cedar and Pocock Creek watersheds. It is probable that Wien's figures, based on censuses in perennial grasslands such as those of the midwest prairies, are too high -- and that two or three species and 100 individuals per km^2 are more reasonable estimates for California. These figures are approximated from observations such as those made in grassland north of Knoxville.

The number of birds on the 33.85 ac. breeding bird census plot is probably representative of serpentine chaparral throughout the study area. Species diversity (12) is comparable to other shrub habitats censused, but the number of individuals per km^2 (554) is considerably lower than the figures given by Wiens (1150) and by Gaines (970). These figures are based on censuses conducted

in shrub habitats growing on nonserpentine soils. Perhaps the lower density of birds on the Cedar Creek census reflects a reduction in primary plant productivity on serpentine soil. Similarity in bird species composition may reflect the physiognomic similarity of serpentine and nonserpentine chaparral vegetation. Additional data are needed to refine these suppositions.

In summary, the diversity and density of birds is several times greater in chaparral than it is in grassland. But as the Pocock and Cedar Creek drainages will not be converted from uniform chaparral to uniform grassland, another factor needs to be considered, namely edge effect.

Where birds live is generally determined by the availability of food, shelter, and nest sites. Any increase in the density and diversity of birds along chaparral-grassland edge would be attributable to species for which the ecotonal habitat is more favorable than either uniform grassland or uniform chaparral. These "edge species" favor ecotones because one habitat provides one or more requisites lacking in the other, and vice versa. In the case of chaparral-grassland edge, the shrubs provide shelter and nesting cover whereas the grasslands provide open foraging ground.

Based on food-shelter-nest criteria, the certain birds of the Pocock and Cedar Creek watersheds can be divided into the following groupings:

Group 1. Birds which forage and find shelter or nest primarily in open grassland.

1. Western Meadowlark

Western Meadowlarks will breed in the clearings created in the chaparral provided grassy or weedy cover is sufficient to conceal nests. During the nonbreeding season (July-February) flocks of meadowlarks can be expected to forage in these clearings. Aggregate numbers will probably increase.

Another ground nesting species, the Horned Lark, may become established as a breeding resident if overgrazing or ORV use denudes the clearings. The larks occur in areas with very sparse vegetative cover.

Meadowlarks and Horned Larks feed on insects when available but seeds of grasses and weeds are their staple foods, particularly in winter.

Group 2. Primarily seed-eating birds which forage in grassland, but find shelter or nest in chaparral.

Resident

1. California Quail
2. House Finch
3. Lesser Goldfinch
4. Brown Towhee
5. Lark Sparrow

Wintering

6. Golden-crowned Sparrow

Summering

7. Mourning Dove

Because annuals are dependent on seeds to survive the summer dry season, they are produced in abundance. The above species of birds feed to a considerable extent on these seeds, particularly in fall and winter when adequate insect food is unavailable. The proposed conversion of chaparral to annual grassland will increase the seed crop from forbs and grasses; hence, at least during the nonbreeding season, the aggregate numbers of these birds will therefore probably increase.

These species are dependent on shrubs for shelter and nesting sites. They usually venture no more than a few yards from cover (except for winter flocks of House Finch and Goldfinch). Thus optimum habitat consists of open grassland interspersed with patches of shrubs.

Like almost all passerines, House Finch, Lesser Goldfinch, Brown Towhee and Lark Sparrow raise their young on a diet composed primarily of insects. Insects appear to be more easily gleaned from woody vegetation than from grassland. In the Santa Cruz Mountains, for instance, another ground dwelling sparrow, the dark-eyed Junco, deserts its usual grassland haunts to glean moth larvae from oak trees while raising young (D. DeSante, pers. comm.). It is therefore uncertain that breeding populations of House Finches, Lesser Goldfinches, Brown Towhees and Lark Sparrows will benefit from conversion of chaparral to grassland. Lesser Goldfinch nests commonly in chaparral (22 territorial males per km^2 on the breeding bird census); hence is unlikely to increase and possibly will decline as a result of the conversion. House Finches, Brown Towhee and Lark Sparrows tend to nest in oak woodland; it is probable, however, that a few pairs will set up housekeeping in the newly created clearings, thereby increasing their aggregate numbers in the area.

California Valley Quail will occupy the chaparral-grassland edge habitat created by the vegetation conversion provided water is available within the birds daily cruising radius. The California Department of Fish and Game estimates that Valley Quail will range up to a mile from water sources and since all of the proposed conversion areas are within this distance from one of the creeks, water is not a problem.

Mourning Doves, which depend heavily on the seeds produced by annual plants for food, will be favored by the conversion.

Group 3. Primarily insect or rodent eating birds which forage in (or over) grassland, but utilize adjacent shrub, trees, fences, etc., for look-out posts and/or nesting sites.

Resident

1. Red-tailed Hawk
2. Golden Eagle
3. Kestrel
4. Great Horned Owl
5. Western Bluebird

Summering

1. Poor-will
2. Western Kingbird

The prey of Red-tailed Hawk, Golden Eagle, and Kestrel are more easily located and captured in grassland than they are in chaparral. The clearings are probably situated within the daily foraging beats of Red-tails and Eagles nesting in the vicinity, therefore these species should benefit. Kestrels will hunt in the clearings, but will probably be unable to find suitable nesting sites (cavities, cliff walls, etc.) in the adjacent chaparral. Similarly Horned Owls and Western Bluebirds will probably occur only as nonbreeding individuals. Unoccupied large nests or cliff ledges suitable as nest sites for Horned Owls are lacking, as are cavities for bluebirds. The broken nature of the presently existing chaparral seems near optimal for Poor-will, as they are fairly common on the breeding bird census plot (22 territorial males per km^2). Poor-wills, therefore, will probably not increase and may decline as a result of vegetation conversion. Western Kingbirds are likely to sally for flying insects over the clearings, but again scattered Digger Pine provide the

only suitable nest sites in adjacent chaparral. A few pairs of Kingbirds will probably nest in the pines, increasing their aggregate breeding population in the area.

Group 4. Primarily gleaning, flycatching or fructivorous birds which forage and shelter (nest) in chaparral and rarely if ever range into open grassland.

Resident

1. Mountain Quail
2. Wrentit
3. Bewick's Wren
4. California Thrasher
5. Rufous-sided Towhee
6. Sage Sparrow

Wintering

7. Hermit Thrush
8. Ruby-crowned Kinglet
9. Fox Sparrow

Summering

10. Ash-throated Flycatcher
11. Blue-gray Gnatcatcher
12. Orange-crowned Warbler

These species depend upon woody vegetation -- hence their aggregate numbers will probably decline as a result of the conversion of chaparral to grassland.

Chaparral broken by occasional small openings, such as is present in the area, provides optimum habitat for Mountain Quail, Bewick's Wren, California Thrasher and Rufous-sided Towhee. The conversion will degrade the habitat for these species by creating large clearings which will not be utilized. None of

the above birds with the exception of the mountain quail normally ventures more than one or two meters from cover. Adverse impact can be ameliorated, however, by leaving as many clumps of woody vegetation within the clearings as possible. The remaining species are even more closely restricted to dense, woody vegetation.

The dependence of these birds on woody vegetation derives primarily from their feeding niches. Wrentit, Ruby-crowned Kinglet, Blue-gray Gnatcatcher and Orange-crowned Warbler are generally insectivorous foliage gleaners in shrubs and trees. Rufous-sided Towhee, Fox Sparrow, and Sage Sparrow forage on the ground, scratching away detritus to get at insects and seeds. Bewick's Wren and California Thrasher also require leaf litter as well as woody vegetation in which to pick and pry for beetles, ants, wasps, larvae, etc. All resident species also feed on the berries of manzanita and other shrubs when these ripen in fall and winter. These berries are a favored food of wintering Hermit Thrushes as well. In some years the berries nourish large flocks of American Robins and Cedar Waxwings and lesser numbers of Varied Thrushes and Band-tailed Pigeons. Ash-throated Flycatchers sally for insects over low vegetation. Their numbers are limited in the area by the paucity of suitable nesting sites (cavities in woody vegetation). Mountain Quail (unlike California Quail) rarely range as far from the dense shrubs beneath whose cover they forage and nest.

Group 5. The following species also occur in chaparral or cypress woodland within the area, but are either uncommon or not easily relegated to the above groupings:

Greater Roadrunner. The habitat requirements of Roadrunner in the North Coast Ranges are poorly understood -- hence it is impossible to predict how the vegetation conversion will affect their aggregate numbers. The species occurs

in scattered areas and is nowhere common. DeSante and LeValley (1972), reviewing the paucity of recent sightings, report that "the future of the scanty Roadrunner population (of Northern California) looks bleak." This may reflect lack of field work rather than a real population decline. Nevertheless, the Roadrunner situation in Northern California warrants study.

Screech Owl. Conversion of Sargent Cypress stands will probably result in a decline of this species in the area.

Anna's Hummingbird. Male Anna's Hummingbirds display and defend territories in the chaparral in the vicinity of such nectar-producing food plants as Chaparral Flowering Current, Indian Warrior and Paintbrush. These plants are rare or absent in open grassland and continuous chaparral, growing principally on chaparral edge. By increasing edge, conversion might increase the abundance of these plants and hence of hummingbirds. On the other hand, these plants are presently common in the many small openings in the existing chaparral. Therefore it is impossible to predict how conversion will affect hummingbirds.

Common Flicker. Occurs primarily in woodland, but a few range into grassland and chaparral. Aggregate wintering population may increase slightly as a result of conversion.

Scrub Jay. Jays are generalists well able to adapt to altered habitat conditions. Still reduction in such prime food sources as acrons and berries accruing from conversion can be expected to somewhat decrease their aggregate population in the area.

Plain Titmouse and Bushtit. Primarily birds of oak woodland, but a few occur in chaparral; hence conversion might reduce their aggregate numbers somewhat.

Hutton's Vireo. Conversion of Sargent Cypress stands will probably result in a decline in this species in the area.

Brown-headed Cowbird. This parasitic bird occurs wherever potential host species are nesting; decline in nesting populations of host species should result in a decline in the numbers of cowbirds. Cowbirds are prone to parasitize the nests of fringillids, warblers, and vireos.

Lazuli Bunting. Not uncommon nesting species in broken chaparral in the vicinity of water, as along Pocock Creek. Conversion in these areas might result in a decline in the aggregate numbers of this species.

Lawrence's Goldfinch. Complete conversion of Sargent Cypress stands will probably result in the extirpation of this species from the area. Lawrence's Goldfinch is of very localized occurrence in Northern California and is nowhere common.

Rufous-crowned Sparrow. An uncommon sparrow localized in open chaparral with intervening patches of herbaceous vegetation, as, for instance, occurs after burns. Impossible to predict impact of conversion on this species.

Of the 28 species (including Horned Lark) considered in the four groupings, 11 (39 percent) are likely to significantly increase in aggregate numbers in the area -- four (14 percent) in open grassland and 7 (25 percent) in chaparral-grassland edge. Twelve species (43 percent) are likely to decline. Impact on the remaining five species (18 percent) could not be predicted with reasonable certainty. The birds are distributed as follows:

Increase in open grassland — Red-tailed Hawk, Kestrel Golden Eagle, Western Meadowlark, Horned Lark, Western Bluebird

Increase in edge — California Quail, Mourning Dove, Western Kingbird, House Finch, Brown Towhee, Lark Sparrow, Golden-crowned Sparrow

Decline -- Mountain Quail, Ash-throated Flycatcher, Wrentit, Bewick's Wren, Blue-gray Gnatcatcher, California Thrasher, Hermit Thrush, Ruby-crowned Kinglet, Orange-crowned Warbler, Rufous-sided Towhee, Sage Sparrow, Fox Sparrow

Uncertain -- Great Horned Owl, Poor-will, Lesser Goldfinch

In summary, more species are likely to decline than are likely to increase. Most of the adversely affected species are closely associated with chaparral vegetation. In contrast the favorably affected birds are widespread in oak-grassland, agricultural, and even suburban habitats.

Available data is inadequate to predict quantitatively the change in bird densities in areas to be converted. It is possible, however, the breeding bird densities will be significantly lower for the following reasons:

1. Many edge species will not be able to find suitable nesting sites in the adjacent chaparral (discussed for particular species above).

2. Except for doves, all birds require animal food (insects, etc.) to feed their young. For many species of birds insects are not as easily obtained in herbaceous vegetation as they are in woody vegetation. Therefore, such species will be at a disadvantage if chaparral habitat is converted to grassland.

3. Chaparral shrubs, because they are able to utilize more of the precipitation than are annual, herbaceous plants, will have a higher net productivity. This will result in more energy available to higher trophic levels, in particular, to birds.

Wintering bird densities are more difficult to predict. The increase in the herbaceous seed crop is likely to be more than offset by the loss of shrub crops such as acorns and berries.

In conclusion, the supposition that the proposed conversion will result in greater numbers of wildlife should be questioned for birds. Decline in both species diversity and overall density is possible. The extent of this decline can be ameliorated by various management practices discussed later in the report.

RESULTS

MAMMALS

A tentative list of the species of mammals which might occur in the study area is given in Appendix III. Table 8 lists the species which were found to be present during the field surveys together with a summary of the probable effects of the proposed chaparral conversion.

Deer pellet counts

In order to obtain a measure of deer density on the study area, pellet counts were made on a number of transects using the method discussed by Robinette et al. (1958).

TABLE 8. Estimated effects of chaparral conversion on species of mammals.

	Positive	Negative	No Probable Effect	Not Possible to Determine at Present
*Mole	X			
Trowbridge shrew				X
Golden long-eared bat				X
Fringed bat				X
Long-legged bat				X
Little California bat				X
Merrian canyon bat				X
Big brown bat				X
Western red bat				X
Hoary bat				X
Lump-nosed bat				X
Pallid bat				X
Mexican free-tailed bat				X
*Black bear			X	
*Raccoon	X			
Ring-tailed cat		X		
Mink	X			
*Spotted skunk	X			
*Striped skunk	X			
Badger	X			
*Gray fox			X	
*Coyote			X	
Mountain lion			X	
*Bobcat			X	
Douglas ground squirrel	X			
*Sonoma chipmunk		X		
Gray squirrel			X	
*Pocket gopher	X			
Pocket mouse	X			
*Kangaroo rat			X	
*Long-tailed harvest mouse	X			
*Gambel white-footed mouse		X		
*Boyle white-footed mouse		X		
*Gilbert white-footed mouse		X		
*Dusky-footed wood rat		X		
*Meadow mouse	X			
*Jackrabbit	X			
*Brush rabbit		X		
*Black-tailed deer	X			

*Species recorded on the study area.

Mil-acre circular plots were employed spaced at 25 yd. intervals along transect lines which were in turn oriented on contour lines. In this way adequate sampling of micro-site differences such as those associated with slope exposure in the chaparral would be adequately sampled. When special emphasis was desired in a particular cover type, a separate series of transects was devoted to it.

Ideally with a resident deer population it is best to use cleared pellet counting plots to determine the time interval involved when the pellets were deposited. Because of the short time span available to carry out field surveys, cleared plots were not used in this case and the pellet deposition time was estimated to be approximately 180 days or six months. Even though this estimate is not precise and absolute numbers of deer inhabiting the areas sampled can therefore only be approximated, still by counting only pellets with a limited degree of weathering it is possible to reduce this source of error to acceptable limits. Likewise even if absolute numbers are not precise, relative density can be determined for the various cover types sampled.

Table 9 indicates the results of the pellet plot counts both in the study area and on and around the test plot near Morgan Valley which had been cleared earlier. In all cases deer use is expressed in deer days/acre based on the 180 day interval cited above and the estimated deer density is per square mile. Pellet counting sites on the study area are shown on Figure 1.

Comparison of deer densities in the Cedar Creek drainage and a natural grassland glade area on the ridge between Cedar and Pocock Creeks with the cleared plot near Morgan Valley and surrounding chaparral indicates a significant increase in deer use in and around the cleared plot. It would appear that the presence of an area of grassland in the midst of an extensive area of chaparral growing on serpentine soil does not necessarily by itself increase deer use as witness the very low density of pellets in the natural glade between Cedar and Pocock Creeks.

TABLE 9. Deer pellet plot counts

Locality	No. Mil-Acre Plots Counted	No. Pellet Groups	Average No. Pellet Groups/Acre	Deer Days Use/Acre For 180 Days	Estimated No. Deer/ Mile^2
Cedar Creek	358	56	156	12	43
Natural Grass Glade on Ridge between Cedar and Pocock Creeks	50	2	40	3	11
Cleared plot near Morgan Valley	311	43	138	11	39
Chaparral surrounding cleared plot near Morgan Valley	112	27	241	19	68

The close relationship between deer use and successional stages of vegetation is well documented. Likewise the seasonal use of grass and forbs during the wet season is also commonly recognized. In the case of the Morgan Valley plot, attractiveness to deer can be explained on the basis of the brush clearing, seeding and fertilizer application resulting in a more attractive mix of grasses and forbs than could be found elsewhere in the local area. Improving the fertility of a site, especially by raising the nitrogen level, increases forage palatability for deer (Oh et al., 1970).

Clearing woody vegetation alone, either brush or trees causes a release of nutrients which can be exploited by successional grasses or forbs whether seeded or natural invaders. This effect is usually transitory lasting only a few years depending upon precipitation levels, soil type and the amount of stored nutrients. However, this effect can be augmented by seeding particularly

palatable and nutritious species of grasses and forbs and by the addition of commercial fertilizers to correct inherent soil deficiencies.

All of these factors probably contributed to the attractiveness of this plot to deer, but it is very probable that since the treatments were carried out several years back, the peak of attractiveness may have passed and if pellet counts had been taken within a year or two post-treatment, the effects would have been greater. Also heavy use of the grasses and forbs in the plot by both deer and jackrabbits had severely depleted the stand thereby reducing its attractiveness during this growing season.

The distribution of pellets in the brush surrounding the plot indicated that deer were concentrated in this area as well. Browse alone, even though it may supply the bulk of the year-long forage intake by deer, does not provide adequate nutrition in the fall and winter months. Browse is most nutritious during the growing season in spring and early summer, but by late summer dormancy sets in and nutrient values, especially protein, decline. Thus if grasses and forbs are available to begin growth following the first fall rains, they supply a valuable forage supplement to deer and many other wildlife species (Longhurst and Connolly, 1970).

In contrast, the very low level of deer use of the natural grassy glade on the ridge between Cedar and Pocock Creeks indicates that it was not attractive to deer nor were deer concentrating in the brush surrounding the glade. Inspection of the glade indicated that it had not been subjected to significant disturbance for a considerable period of time. The vegetation in the glade had therefore largely stabilized and the stand was now predominantely species of annual and native perennial grasses which are not very attractive to deer. Likewise the low component of forbs was not composed of species which are particularly palatable.

Even though this area is in a grazing allotment, cattle use had been very light so that this potential source of disturbance was not effective. The net result was that the glade in its present condition was not providing as much deer forage as the surrounding chaparral. Although quantitative counts were not made, it was evident that the density of jackrabbit pellets in the glade was much lower than in the plot near Morgan Valley.

Small mammal trapping showed that the general density of rodents in the study area was moderate. A total of 400 trap nights yielded 22 mice, 18 Gambel white-footed mice, 1 Boyle white footed mouse, and 3 long-tailed harvest mice. Although no Gilbert white-footed mice were trapped, one was found drowned in an abandoned water trough on the ridge between Cedar and Pocock Creeks. Trapping sites are indicated on Figure 1.

Species diversity of small rodents based on the trapping results, other field observations and examination of the tentative list of mammals indicates an average assortment for this part of California. As compared to chaparral growing on nonserpentine soils, no comparative information on densities of small rodents were available, but species diversity appears to be quite similar to that in the study area.

Probable Effects of Chaparral Conversion on Mammal Species

Mole -- In this area most mole activity would be in riparian situations, but some extends into grassland. An increase in grassland would be beneficial.

Trowbridge shrew -- The habitat requirements and limitations of this shrew are not sufficiently well known to predict the effects of chaparral conversion.

Bats -- Possible roosting sites would be reduced by removing chaparral, but the effects of such conversion on the insect species which bats feed upon are beyond the scope of this study.

Black bear -- This general area has been marginal habitat for black bear for many years as indicated by the very sparse population compared with areas farther north in the Mendocino National Forest. Cover is adequate, but a year-round food supply is probably inadequate to support many bears. Since bears range over considerable areas, the small acreage proposed for conversion should have little net effect.

Raccoon -- Because raccoons are omnivorous and depend upon both chaparral and grassland for food, increasing the cover type diversity should prove beneficial to them.

Ring-tailed cat -- This species is closely associated with chaparral and the proposed conversion would reduce the area of its usable habitat.

Mink -- It is unlikely that mink would occur along Cedar or Pocock Creeks, but they may occasionally visit Hunting Creek. Augmentation of the water flow through chaparral conversion would be beneficial in Hunting Creek and downstream in Putah Creek.

Skunks -- Both spotted and striped skunks have a broad spectrum of food items, primarily insects, small mammals, birds, eggs, reptiles amphibia etc. Therefore increasing habitat diversity through chaparral conversion should be beneficial to them.

Badger -- The badger is dependent upon burrowing rodents for food and such species as ground squirrels and gophers would be of primary importance in the study area. Increasing the grassland areas would benefit these rodents and in turn the badger.

Gray fox -- Although this fox is a fairly wide ranging and quite omnivorous species, it is probable that on balance it obtains more of its food from chaparral than grassland. However, it would be difficult to determine whether the net effect of the chaparral conversion in the amount proposed would have a measurable effect on the fox population.

Coyote -- The coyote is a wide ranging animal, with omnivorous food habits. It is possible that diversification of the habitat through brush conversion may be of some benefit, but on the scale proposed the effects of the conversion would be virtually impossible to measure. A number of the species of rodents which coyotes rely upon to a considerable extent for food are dependent upon chaparral and the potential for negative effects on the coyote are also present.

Mountain lion -- Very few lions occur in this area and since they are so wide ranging the impact of the proposed brush conversion would be insignificant. However, since their primary prey, deer, would be benefitted, the lion in turn may benefit. On the other hand, there are already more than enough deer in the area to feed all the lions which conceivably might be present.

Bobcat -- The bobcat is generally rather localized in its movements as compared with a fox or coyote and many of its prey rodents, brush rabbit, etc. are dependent on chaparral. However, on balance other rodents which it takes are tied to grassland and it probably would be difficult to discern any change in the bobcat population as a result of the brush conversion.

Douglas ground squirrel -- An increase in grassland as a result of brush conversion will favor this species. Likewise if livestock grazing is practiced, conditions will be more favorable because of this squirrel's predilection for short grass maintained at a low successional stage.

Sonoma chipmunk -- This small squirrel is usually found only in thick, mature stands of chaparral so that conversion of chaparral to grassland would reduce its habitat.

Gray squirrel -- At best the only possible habitat for gray squirrels on the study area is the riparian association along Cedar, Pocock, and Hunting Creeks and even these areas are marginal. Since brush conversion is to be confined to ridge tops there will be no direct effects on this species.

Pocket gopher -- Grassland with its associated forbs for food is a much more suitable habitat for gophers than chaparral. The conversion will therefore improve conditions for them.

Pocket mouse -- The possibility that this species exists in the study area is only tenuous (Longhurst, 1940:262). If it does, the conversion of brush to grass would probably be favorable to it.

Kangaroo rat -- This species of heteromyid rat is found in low numbers throughout chaparral areas in the coast ranges. Although its primary food is seeds of grasses and forbs, it seems to prefer chaparral or edge areas where chaparral and grassland meet. The net effect of the proposed conversion would be slight for this species as the loss of chaparral habitat would be balanced by the increase in edge area.

Long-tailed harvest mouse -- Since this mouse is closely associated with grassland as its habitat, the brush conversion program would definitely improve conditions for it.

White footed mice -- The three species of white-footed mice are sometimes found in grassland, but much more frequently they are associated with woody vegetation, trees and brush. Since they are seed eaters, they would no doubt be benefitted by the edge effect created by brush conversion to grassland and take advantage of the increased supply of grass and forb seeds. However, the reduction in cover provided by chaparral would more than counterbalance such positive effects.

Dusky-footed wood rat -- The wood rat habitat in the study area is definitely in the chaparral. Therefore any reduction in chaparral acreage would reduce their available habitat accordingly.

Meadow mouse -- In contrast to the wood rat, meadow mice are tied to grassland habitat and thrive best in tall grass. Increasing the grassland through the proposed conversion would obviously be beneficial for this species, but if heavy livestock grazing is allowed, the quality of the grassland will be lowered for them.

Jackrabbit -- Although jackrabbits may use chaparral for cover they do most of their foraging in grassland and thrive well in open grassland. Lower successional stages of grassland seem to be most favorable for them and livestock grazing would improve their status.

Brush rabbit -- The brush rabbit contrasts with the jackrabbit in that it is definitely dependent on chaparral for cover. The increase in edge as a result of the conversion would be beneficial for them, but the net effect of the conversion would on balance be detrimental.

Black-tailed deer -- As discussed earlier in this report in relation to deer pellet counts, the conversion program would be beneficial for deer. Also if the grassland produced is grazed by livestock, benefits will be increased significantly.

Recommendations

The proposed conversion of chaparral to grassland will affect vertebrates in a number of different ways depending upon the habitat requirements and food habits of individual species. In spite of any mitigating measures which can be employed, certain species which are highly dependent upon the chaparral cover type or associated cypress stands, will suffer as a result of this project. However, with certain modifications of the conversion procedure and of follow-up management practices, wildlife benefits can be greatly enhanced for a number of species, both game and nongame.

Modifications of treatments such as the ones suggested here should serve to alleviate much of the public oppostion to brush conversion practices designed

primarily for water yield enhancement with little compromise of the basic objective.

1. Maximize the amount of edge through making the margins of the converted areas as irregular as possible.
2. Leave as many small islands of brush and trees as possible in the treated areas. Even individual bushes or islands two or three yards in diameter will be useful, but islands five to ten yards or larger in diameter will be more beneficial.
3. If herbicide sprays are used to control brush sprouts or seedlings, care should be exercised to avoid killing the choice deer browse species where possible. Broadcast spray applications are notoriously unselective and the choice browses such as the various species of Caenothus, Cerocarpus, Fraxinus, and Rhamnus will be killed along with the undesirable manzanita and cypress. If deer are adequately controlling the growth of chamise and oak, for example, and keeping the bushes hedged to a low level, little will be gained in terms of reducing transpiration by application of herbicides. Actually in many cases the impact of deer browsing alone is sufficient to drastically reduce the density of the more palatable browse species in chaparral which has been burned or mechanically treated. The intensity of such deer browsing will vary with the density of deer in the vicinity and the size of the area burned or treated.
4. Livestock grazing of converted areas is one of the most important follow-up practices if carried out on a carefully prescribed basis. Grazing is not only necessary for maintenance of the stand of seeded grasses and legumes, but also to maintain the proper vegetational succession stage to yield most benefits for a number of forms of wildlife, particularly the game species -- deer, quail, and doves.

Grazing should be moderately intense and should be initiated at least by the second growing season after the areas are seeded. Early season grazing is important commencing in February or early March and continuing until about mid-April. At that time livestock should be withdrawn or significantly reduced to allow the seeded annual grasses and legumes to set seed. After the range dries up, usually by mid-May, additional grazing during the summer and fall is not detrimental.

To achieve best results from grazing in terms of both livestock production and wildlife benefits, a combination of sheep and cattle should be used. It is evident that the part of Napa County where the study area is located has not historically been a sheep production area. To run sheep in this locality would present problems for a private livestock operator both from an economic standpoint and because of the potential for coyote predation. However, there are substantial benefits to be gained from the impact of prescribed sheep grazing in this range situation and consideration should be given to using them. Cattle grazing alone does not yield the full potential of benefits for wildlife that are possible if sheep are run on the area as well.

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APPENDIX A. TENTATIVE LIST OF REPTILES AND AMPHIBIANS IN CEDAR CREEK AND POCOCK CREEK DRAINAGES.

AMPHIBIANS

Common Name	Species
California Newt	Taricha torosa
Ensatina	Ensatina eschscholtzi
California Slender Salamander	Batrachoseps attenuatus
Arboreal Salamander	Aneides lugubris
Western Toad	Bufo boreas
Pacific Treefrog	Hyla regilla
Foothill Yellow-legged Frog	Rana boylei

Additional species likely along Hunting Creek:

Rough-skinned Newt	Taricha granulosa
Red-legged Frog	Rana aurora
Bullfrog	Rana catesbeiana

REPTILES

Western Fence Lizard	Sceloporus occidentalis
Coast Horned Lizard	Phrynosoma coronatum
Western Skink	Eumeces skiltonianus
Western Whiptail	Cnemidophorus tigris
Southern Alligator Lizard	Gerrhonotus multicarinatus
Ringneck Snake	Diadophis punctatus
Sharp-tailed Snake	Contia tenuis
Racer	Coluber constrictor
Coachwhip	Masticophis flagellum
Striped Racer	Masticophis lateralis
Gopher Snake	Pituophis melanoleucus
Common Kingsnake	Lampropeltis getulus
Common Garter Snake	Thamnophis sirtalis
Western Terrestrial Garter Snake	Thamnophis elegans
Long-nosed Snake	Rhinocheilus lecontei
Night Snake	Hypsiglena torquata
Western Rattlesnake	Crotalus viridus

Additional species likely along Hunting Creek:

Western Aquatic Garter Snake	Thamnophis couchi
Pacific Pond Turtle	Clemmys marmorata

Additional species possible in area:

Sagebrush Lizard	Sceloporus graciosus
Northern Alligator Lizard	Gerrhonotus coeruleus
Rubber Boa	Charina bottae
California Mountain Kingsnake	Lampropeltis zonata

APPENDIX B. TENTATIVE LIST OF BIRDS IN CEDAR AND POCOCK CREEK DRAINAGES.

Common Name	Species
Great Blue Heron	Ardea herodias
Turkey Vulture	Cathartes aura
Cooper's Hawk	Accipiter cooperii
Sharp-shinned Hawk	Accipiter striatus
Red-tailed Hawk	Buteo jamaicensis
Golden Eagle	Aquila chrysaetos
Prairie Falcon	Falco mexicanus
Merlin	Falco columbarius
Kestrel	Falco sparverius
Mountain Quail	Oreortyx picta
California Quail	Callipepla californica
Band-tailed Pigeon	Columba fasciata
Mourning Dove	Zenaidura macroura
Greater Roadrunner	Geococcyx californianus
Screech Owl	Otus asio
Great Horned Owl	Bubo virginianus
Pygmy Owl	Glaucidium gnoma
Poor-will	Phalaenoptilus nuttallii
White-throated Swift	Aeronautes soxatilis
Anna's Hummingbird	Calypte anna
Rufous Hummingbird	Selasphorus rufus
Allen's Hummingbird	Salasphorus sasin
Calliope Hummingbird	Stellula calliope
Belted Kingfisher	Megarceryle alcyon
Common Flicker	Colaptes auratus
Pileated Woodpecker	Dryocopus pileatus
Acorn Woodpecker	Balanosphyra formicivora
Lewis' Woodpecker	Asyndesmus lewis
Yellow-bellied Sapsucker	Sphyrapicus varius
Hairy Woodpecker	Dendrocopus villosus
Downy Woodpecker	Dendrocopus pubescens
Nuttall's Woodpecker	Dendrocopus nuttallii
Western Kingbird	Tyrannus verticalis
Ash-throated Flycatcher	Myiarchus cinerascens
Black Phoebe	Sayornis nigricans
Say's Phoebe	Sayornis saya
Willow Flycatcher	Empidonax trailli
Hammond Flycatcher	Empidonax hammondii
Dusky Flycatcher	Empidonax wrightii
Western Flycatcher	Empidonax difficilis
Western Wood Pewee	Contopus sordidulus
Olive-sided Flycatcher	Nuttallornis borealis
Violet-green Swallow	Tachycineta thalassina
Tree Swallow	Iridoprocne bicolor
Rough-winged Swallow	Stelgidopteryx ruficollis
Barn Swallow	Hirundo rustica

Cliff Swallow	Petrochelidon pyrrhonota
Purple Martin	Progne subis
Scrub Jay	Aphelocoma californica
Raven	Corvus corax
Common Crow	Corvus brachyrhynchos
Plain Titmouse	Parus inornatus
Bushtit	Psaltriparus minimus
White-breasted Nuthatch	Sitta carolinensis
Wrentit	Chamaea fasciata
Dipper	Cinclus mexicanus
House Wren	Troglodytes aedon
Bewick's Wren	Thryomanes bewickii
Canyon Wren	Catherpes mexicanus
Rock Wren	Salpinctes obsoletus
California Thrasher	Toxostoma redivivium
American Robin	Turdus migratorius
Varied Thrush	Ixoreus naevius
Hermit Thrush	Hylocichla guttata
Swainson's Thrush	Hylocichla ustulata
Western Bluebird	Sialia mexicana
Townsend Solitaire	Myadestes townsendi
Blue-gray Gnatcatcher	Polioptila caerulea
Golden-Crowned Kinglet	Regalus satrapa
Ruby-Crowned Kinglet	Regalus calendula
Cedar Waxwing	Bombycilla cedrorum
Phainopepla	Phainopepla nitens
Hutton's Vireo	Vireo huttoni
Solitary Vireo	Vireo solitarius
Warbling Vireo	Vireo gilvus
Orange-crowned Warbler	Vermivora celata
Nashville Warbler	Vermivora ruficapilla
Yellow Warbler	Dendroica petechia
Yellow rumped Warbler	Dendroica coronata
Black-throated Gray Warbler	Dendroica nigrescens
Townsend Warbler	Dendroica townsendi
Hermit Warbler	Dendroica occidentalis
MacGillivray's Warbler	Oporornis tolmiei
Wilson's Warbler	Wilsonia pusilla
Western Meadowlark	Sturnella neglecta
Brewer's Blackbird	Euphagus cyanocephalus
Brown-headed Cowbird	Molothrus ater
Western Tanager	Piranga ludoviciana
Black-headed Grosbeak	Pheucticus melanocephalus
Lauli Bunting	Passerina amoena
Purple Finch	Carpodacus purpureus
House Finch	Carpodacus mexicanus
Pine Siskin	Spinus pinus
American Goldfinch	Spinus tristis
Lesser Goldfinch	Spinus psaltria

Lawrence's Goldfinch	Spinus lawrencei
Rufous-sided Towhee	Pipilo maculatus
Brown Towhee	Pipilo fuscus
Lark Sparrow	Chondestes grammacus
Rufous-crowned Sparrow	Aimophila ruficeps ruficeps
Sage Sparrow	Amphispiza belli belli
Dark-eyed Junco	Junco hyemalis
Chipping Sparrow	Spizella passerina
White-crowned Sparrow	Zonotrichia leucophrys
Golden-crowned Sparrow	Zonotrichia atricapilla
Fox Sparrow	Passerella iliaca
Lincoln Sparrow	Melospiza lincolnii
Song Sparrow	Melospiza melodia

APPENDIX C. TENTATIVE LIST OF MAMMALS IN THE CEDAR AND POCOCK CREEK DRAINAGES.

Common Name	Species
Mole	Scapanus latimanus
Trowbridge shrew	Sorex trowbridgii
Golden long-eared bat	Myotis evotis
Fringed bat	Myotis thysanodes
Long-legged bat	Myotis volans
Little California bat	Myotis californicus
Merrian canyon bat	Pipistrellus hesperus
Big brown bat	Eptesicus fuscus
Western red bat	Lasiurus borealis
Hoary bat	Lasiurus cinereus
Lump-nosed bat	Corynorhinus rafinesquii
Pallid bat	Antrozous pallidus
Mexican free-tailed bat	Tadarida mexicana
Black bear	Ursus americanus
Raccoon	Procyon lotor
Ring-tailed cat	Bassariscus astutus
Mink	Mustela vison
Spotted skunk	Spilogale gracilis
Striped skunk	Mephitis mephitis
Badger	Taxidea taxus
Gray fox	Urocyon cinereoargenteus
Coyote	Canis latrans
Mountain lion	Felis concolor
Bobcat	Lynx rufus
Douglas ground squirrel	Spermopholis beecheyi
Sonoma chipmunk	Eutamias sonomae
Gray squirrel	Sciurus griseus
Pocket gopher	Thomomys bottae
Pocket mouse	Perognathus inornatus
Kangaroo rat	Dipodomys heermanni
Long-tailed harvest mouse	Reithrodontomys megalotis
Gambel white-footed mouse	Peromyscus maniculatus
Boyle white-footed mouse	Peromyscus boylii
Gilbert white-footed mouse	Peromyscus truei
Dusky-footed wood rat	Neotoma fuscipes
Meadow mouse	Nicrotus californicus
Jackrabbit	Lepus californicus
Brush rabbit	Sylvilagus bachmani
Black-tailed deer	Odocoileus hemionus

APPENDIX D. CHAPARRAL BREEDING BIRD CENSUS PLOT VEGETATION ANALYSIS.

Data is derived from 12 line transects spaced 100 meters apart and extending in a straight line alternatingly 10 meters NE and 10 meters SW of the fire road which bisects the plot. For each square meter along a transect woody species present were recorded by percent cover (estimated to nearest 10 percent) and vegetation height.

Transect	Height (range)	Percent cover (range)
1	1.0 m (0-1.8)	40 (0- 80)
2	1.1 m (0-1.5)	60 (0-100)
3	1.2 m (.9-1.5)	80 (20- 90)
4	1.0 m (0-1.8)	40 (0-100)
5	.4 m (0- .9)	20 (0- 80)
6	1.7 m (1.2-2.4)	60 (10-100)
7	1.6 m (0-3.0)	50 (0-100)
8	1.8 m (.6-3.0)	70 (50-100)
9	2.5 m (1.5-3.6)	80 (30-100)
10	.9 m (0-2.4)	60 (0-100)
11	.8 m (0-1.8)	40 (10- 90)
12	1.4 m (.9-2.1)	60 (30-100)
Mean	1.3 m	70

Species	Relative Dominance[1]	Frequency[2]
Adenostoma fasciculatum	34%	38%
Arctostaphylos viscida	32%	28%
Quercus durata	27%	34%
Ceanothus jepsonii	3%	5%
Cupressus macnabiana	2%	4%
Garrya congdonii	1%	3%
Ceanothus cuneatus	1%	2%
Heteromeles arbutifolia	TRACE	TRACE
Eriodictylon californica	TRACE	TRACE

[1] Relative dominance -- $\frac{\text{total percent cover of the species}}{\text{total percent cover of all species}}$

[2] Frequency -- $\frac{\text{number of square meters in which species occurred}}{\text{total number of square meters in transects}}$